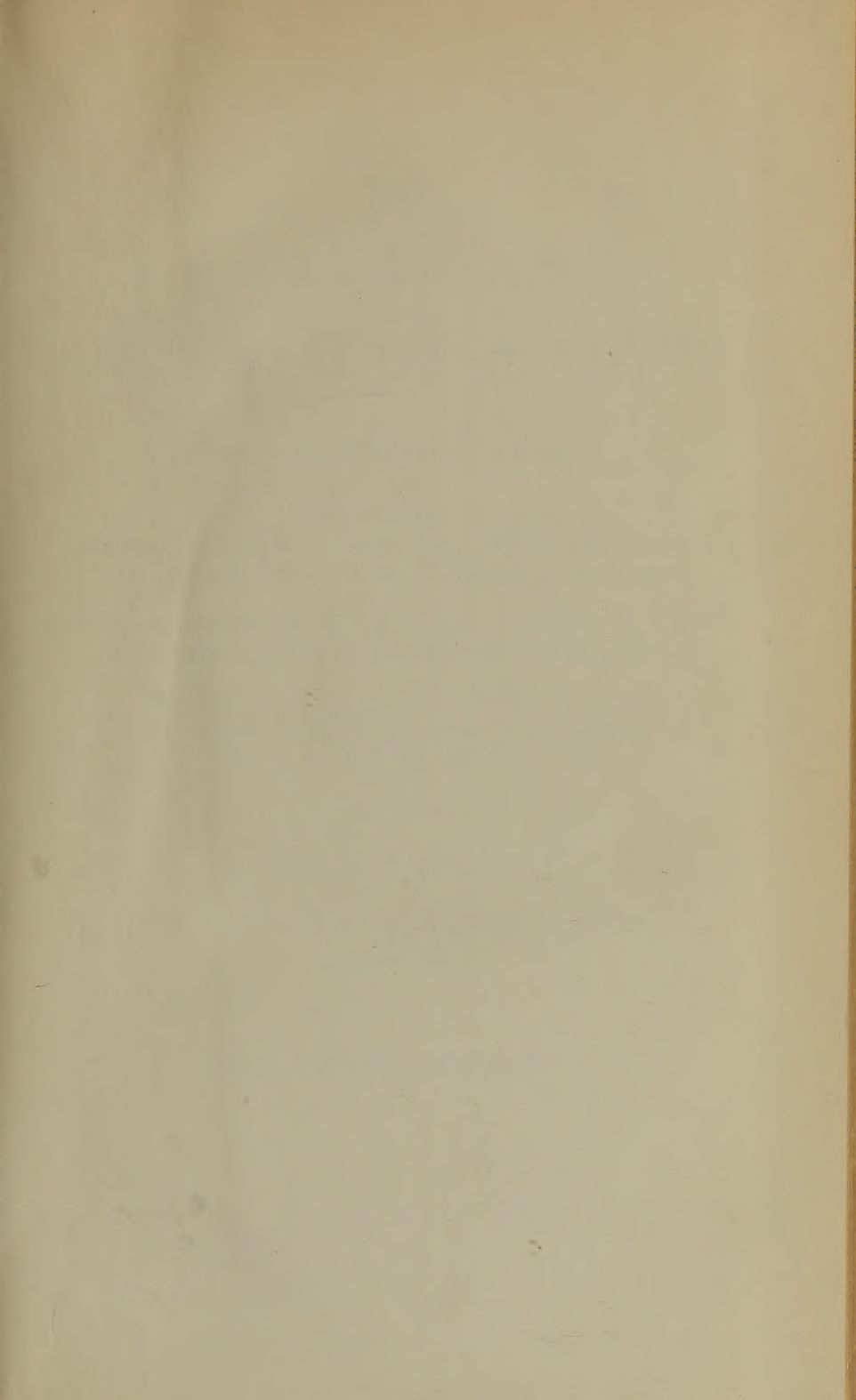




Geology

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THE
AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

ART. I.—*The Platinum-Rhodium Thermoelement from 0° to 1755°*; by ROBERT B. SOSMAN.

CONTENTS :

1. Introduction and Plan.
2. Scale of Temperatures.
3. Melting Point of Platinum.
4. Interpolation.
5. Relation of Thermal E.M.F. to Composition.
6. Summary.

1. Introduction and Plan.

IN two recent papers from this laboratory,* there have been published the results of a revision of the nitrogen thermometer scale from 400° to 1100° and of an extension of the scale to 1550°. The plan of that research was essentially as follows : it consisted, first, in selecting certain fixed thermometric points, usually melting points of metals, and in determining their reproducibility ; second, in making a measurement of the true temperature on the nitrogen scale at or close by one of these fixed points ; third, in transferring this known temperature by means of a thermoelement over to the fixed point in question. This transference by the thermoelement was necessary because the platinum-rhodium thermometer bulb could not be put directly into melting or solidifying substances at high temperatures.

A portion of the second paper† was taken up with a discussion of the standardization of the platinum-rhodium

* Some New Measurements with the Gas Thermometer, A. L. Day and J. K. Clement, this Journal (4), xxvi, 405-463, 1908 ; The Nitrogen Thermometer from Zinc to Palladium, A. L. Day and R. B. Sosman, *ibid.* (4), xxix, 93-161, 1910.

† Loc. cit., pp. 121-128, 140, and 147-151.

thermoelement. It was shown that the relation of thermal e.m.f. to temperature can be represented over the range studied (400° to 1550°) by two parabolic curves, by means of which temperatures between the standard melting points can be interpolated with an average accuracy of one degree.

Since this thermoelement can be conveniently used for the measurement of temperatures beyond 1550° , continuing up to the melting point of the platinum wire at 1755° , it was thought desirable to extend its interpolation curve to cover the region between palladium and platinum (1549° – 1755°). In this region the thermoelement is the most accurate means we have for measuring temperatures. Below 300° , on the other hand, the sensitiveness of the platinum-rhodium element is very low compared with the platinum resistance thermometer, the copper-constantan thermoelement, or the mercury thermometer. Nevertheless, it is often convenient to use this element for measurements in the lower range; hence we have in addition determined the course of the thermoelement curve from 0° to 300° . The present paper contains the results of these extensions in the form of a table, which has been found very convenient in this laboratory for the thermoelectric measurement of all temperatures from 0° to 1775° .

In connection with the work on the nitrogen thermometer referred to above, some data were obtained on the thermal electromotive force of rhodium alloys of various compositions, which have been brought together with the few earlier determinations that are available, to show the relation of the thermal e.m.f. to the percentage of rhodium in the alloy.

2. Scale of Temperatures.

The melting and boiling points of pure substances form the best basis for the calibration of secondary measuring devices, such as the thermoelement, after these points have once been determined on the gas thermometer. The 0° and 100° points are familiar. In the neighborhood of 200° and 300° the boiling points of pure naphthalene and benzophenon were used. The best gas thermometer determinations of these two points, by Callendar and Griffiths,* and by Jaquero and Wassmer,† differ by 0.26° at 218° and 0.4° at 305° . We have adopted the data of Jaquero and Wassmer, until further gas thermometer measurements shall have brought out the reasons for these differences. The values are 217.68° for naphthalene and 305.44° for benzophenon, at 760^{mm} pressure.‡

* Phil. Trans. Roy. Soc., clxxxii, A, 43-72, 119-157, 1892.

† Jour. Chim. Phys., ii, 52-78, 1904.

‡ The results of Jaquero and Wassmer have been used as the standard since 1904 by the Research Laboratory of Physical Chemistry at the Massachusetts Institute of Technology, in their work on electrical conductivity at high temperatures.

In our revision of the nitrogen scale from zinc to palladium,* one measurement was made at the melting point of cadmium, to give an indication of the course of the thermoelement curve. Being only a single measurement, this has not as much weight as the higher temperatures, which were measured under varied conditions. The value obtained was 320.0° . The difference between benzophenon and cadmium, determined with three thermoelements, is 14.9° , which agrees within 0.1° with a similar comparison made at the Bureau of Standards, using a resistance thermometer and different samples of the materials.

On the basis of the benzophenon value adopted above, this difference makes the cadmium point 320.3° . We have arbitrarily connected the two portions of the temperature scale at this point by taking the mean, 320.2° , for cadmium. Since in this region temperatures cannot be conveniently obtained closer than 0.2° with the platinum-rhodium element, the values are abundantly accurate for our present purpose.

From zinc to palladium, we have used, throughout, the scale of temperatures published in our recent paper.†

It should not be overlooked that the value which we have used for zinc indicates a lower value for the boiling point of sulphur than the figure 444.5 now in general use. The four independent gas thermometer determinations that have been made of the sulphur point, although agreeing unusually well, are not free from the possibility of errors of several tenths of a degree, and this fact, taken together with the variability in the point itself with different experimental conditions, makes it probable that the absolute value given for the sulphur point is at least no more reliable than the value given below for the zinc point.

3. Melting Point of Platinum.

For the purpose of interpolating between the melting points of palladium and platinum, it was necessary to determine, on a number of thermoelements, the thermal e.m.f. at the latter temperature. This was done by heating the element up to the melting point of the platinum wire, within a glazed Marquardt porcelain tube, in the region of maximum temperature of a resistance furnace. The furnace was of the carbon tube type.‡ Carbon monoxide around the outside of the porcelain tube protected the furnace from oxidation, and a current of dry air in the inside prevented contamination of the thermoelement. Both wires of the element were enclosed in Marquardt capillaries, leaving only about 2^{mm} of the platinum exposed next to the junction. It was always this portion that

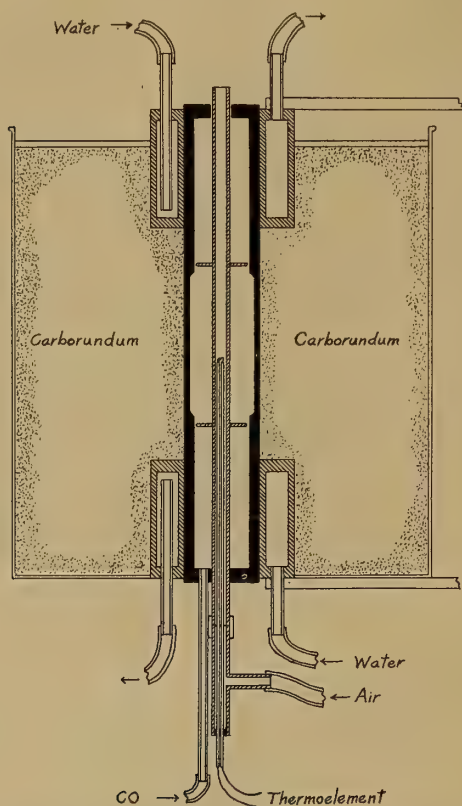
* Loc. cit.

† Loc. cit., p. 161.

‡ S. A. Tucker, Trans. Amer. Electrochem. Soc., xi, 303, 1907.

melted, the point being marked by a halt of about one minute in the gradual rise in temperature of the element, preceding the formation of a globule and the interruption of the circuit. New Marquardt tubes were used for each determination. Several elements were examined for contamination after the measurement,* and no appreciable amount was found. A vertical section of the furnace is shown in fig. 1.

FIG. 1.



Carbon-tube furnace for melting point of platinum. Scale, 1 : 4.

In Table I are given the experimental results. The values are in microvolts, corrected as discussed in the paper already referred to.† The silver point, being about half way between 0° and platinum, is included in order to indicate the general course of the interpolation curve.

* Method described in Day and Sosman, loc. cit., p. 116.

† Day and Sosman, loc. cit., p. 115.

With these are included the results obtained by other observers with similar ten per cent rhodium alloys. Harker* measured the e.m.f. at the melting point of the platinum wire in a resistance furnace of refractory oxides. Waidner and Burgess† made similar measurements in connection with their optical determination of the melting point. Their figures, being in terms of the United States legal volt (Clark at $15^{\circ} = 1.434$) have been corrected to the true volt (Clark at $15^{\circ} = 1.4328$). Other investigators (Holborn and Henning,‡ Nernst and von Wartenberg,§ Holborn and Valentiner||) have measured the melting point of platinum in various ways, but without recording the thermoelectric data.

TABLE I.—THERMAL E.M.F. AT MELTING POINT OF PLATINUM.

Date	No. of Element	Per cent Rh in alloy wire	Silver microvolts	Platinum microvolts
1910—19 Feb.---	F	10	9103	18619
24 Feb.---	F	10	9103	18613
25 Feb.---	Y	10	9139	18695
25 Feb.---	Z	10	9018	18487
8 Mar.---	J	10	9106	18603
1 Mar.---	I ₁ J	1	1960	3560
15 Apr.---	KJ	5	6495	12444
2 Mar.---	I ₁₅ J	15	10375	22303
4 Mar.---	I ₁₅ J	15	10375	22310
1905—Harker---	N. P. L. 3	10	(9084)	18580
" "---	T. 15	10	(9100)	18693
1907—W. and B.	P 2	10	(9024)	18369
" "---	P 3	10	(9040)	18556
" "---	S ₁	10	(8991)	18250

In general, the curves for all the different 10 per cent elements, both our own and those of other observers, are similar in form, and the divergence of each from the mean increases with increasing temperature. In this connection it should be remarked that the e.m.f. at the palladium point (16140 microvolts) obtained by Holborn and Valentiner with an element whose gold point was 10295, agrees almost exactly with a similar element from our series, with a gold point of 10295 and palladium point of 16143. The disagreement between various observers as to the melting points of these metals is, then, not so much a matter of purity of metals or accuracy of thermoelectric measurements, as it is of the evaluation of these in terms of the nitrogen thermometer.

It is of interest to find what value would be obtained for the melting point of platinum by extrapolating the curves of our

* J. A. Harker, Proc. Roy. Soc., lxxvi, A, 235-250, 1905.

† C. W. Waidner and G. K. Burgess, Bull. Bur. Standards, iii, 200, 1907.

‡ L. Holborn and F. Henning, Sitzb. Berl. Akad., xii, 311-317, 1905.

§ W. Nernst and H. von Wartenberg, Ber. deut. Phys. Ges., iv, 48-58, 1906.

|| L. Holborn and S. Valentiner, Ann. Phys., xxii, 1-48, 1907.

own elements, on which we have complete data, using for this purpose the portion of the curve from 1100° to 1550° . A parabola passed through the melting points of copper (1082.6°), diopside (1391.2°) and palladium (1549.2°), gives, in the case of the various 10 per cent elements, values for platinum from 1748° to 1753° ; the 1 per cent alloy gives 1750° – 1755° (low sensitiveness); the 5 per cent, 1752° ; and the 15 per cent, 1755° . The mean is 1752° .

In the preceding paper it was pointed out* that the available optical determinations of the melting points of palladium and platinum agree very well as to the *difference* between these two points, although disagreeing as to their absolute value. The mean value of this difference is 206° . Having fixed the palladium point on the nitrogen thermometer, we were able therefore to give the melting point of platinum as 1755° with an estimated accuracy of 5° . The extrapolated value in the preceding paragraph agrees with this figure, 1755° , within the estimated limit of accuracy.

A parallel case to this is found in the values obtained by extrapolating the resistance thermometer above 500° , which come remarkably close to those obtained by the nitrogen thermometer, but which should not on that account be given equal weight with a real measurement. There is no reason to expect that such extrapolation will give true results, for the *downward* extrapolation of the thermoelement equation, and likewise of the resistance thermometer,† goes far astray. The extrapolated values given above for platinum should therefore be considered as merely confirmatory, not as having any independent weight, and we have accordingly, in calculating the interpolation curve for the thermoelement from 1550° to 1750° , used our original value of 1755° for platinum.‡

The summarized temperature scale adopted for present use in this laboratory for the calibration of thermoelements is as follows:

Ice, m. p.	0°
Water, b. p.	$100.0^{\circ} + 0.037 (p-760)$
Naphthalene, b. p.	$217.7^{\circ} + 0.057 (p-760)$
Benzophenon, b. p.	$305.4^{\circ} + 0.063 (p-760)$
Cadmium, m. p.	320.2°
Zinc, m. p.	418.2°
Antimony, m. p. (in CO)	629.2°
Silver, m. p. (in CO)	960.0°
Gold, m. p.	1062.4°
Copper, m. p. (in CO)	1082.6°

* Day and Sosman, loc. cit., p. 160.

† Travers and Gwyer, Zeitschr. phys. Chem., lli, 437, 1905.

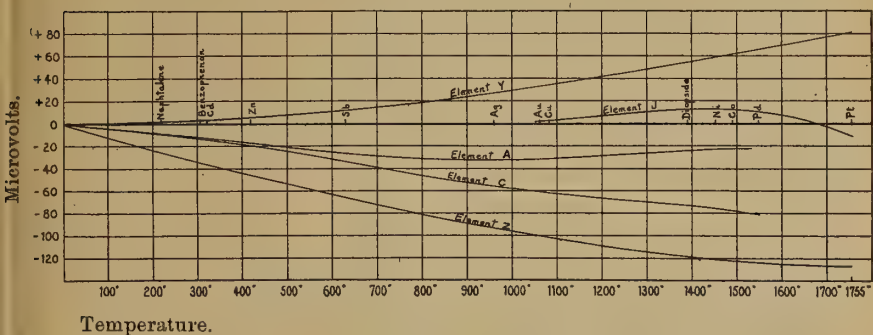
‡ In view of these facts, it is evident that Harker's figure, 1710° , obtained by extrapolating the curves of a number of platinum-rhodium and platinum-iridium thermoelements from 1100° up to their melting points, has little or no value as an estimate of the melting point of platinum.

Diopside, m. p.	1391.2°
Nickel, m. p. (in N ₂)	1452.3°
Cobalt, m. p. (in N ₂)	1489.8°
Palladium, m. p.	1549.2°
Platinum, m. p.	1755°

4. Interpolation.

For interpolation between these points we may use either an empirical equation or series of equations, or we may plot the temperatures and microvolts and draw a smooth curve through the points. The results of one method have no better claim to accuracy than the results of the other, for an empirical equation is essentially nothing but an imaginary curved ruler. A plotted curve on a scale large enough to get the requisite accuracy of reading would, however, take a sheet at least 30

FIG. 2.



Deviation of typical thermoelements from standard curve.

feet square. But if instead of plotting microvolts directly against degrees, we plot the *deviation* from the straight line, $e = 10t$, the sheet required is reduced to about 3 feet square. If further, we plot the deviations of each element from an *arbitrary standard curve*, instead of the deviations from a straight line, the usual 50^{cm} × 40^{cm} sheet is ample.

The figures of Table II represent such a curve, which lies very close to the actual curve for the standard thermoelement E used in the work on the nitrogen thermometer. It is made up of several parabolas connected by transition curves. The deviations of various other elements, in use in the laboratory, from this standard are plotted in fig. 2. These curves are obtained by plotting the differences between the reading of the element and that of the assumed standard at each calibration point.

An example will serve to make clear the method of converting microvolts into degrees with this table and curve. It is

desired to find the temperature corresponding to a reading of 8931 microvolts on element Z. It is evident from the table that the temperature is in the neighborhood of 950° . At about this temperature, element Z reads 92 microvolts below the assumed standard; adding 92 microvolts to 8931 gives 9023 microvolts as the corresponding standard reading, and this by interpolation in the table gives 952.3° . The tenths, of course, mean little in absolute value; but temperature *differences*, in case measurements are made with similar elements under similar conditions, can often be obtained to tenths of a degree.

The use of this table and deviation-curve avoids the calculation and recalculation of thermoelement curves and the tabulation of their readings. If the calibration of an element changes by a few microvolts, the deviation-curve is merely raised or lowered by a corresponding amount. If the value adopted for one of the calibration points is changed, the corresponding reading in microvolts of the assumed standard is also changed, and all the deviation-curves take a slightly different course in the neighborhood of that point. The table and curves make it possible, furthermore, to estimate temperatures (with an accuracy of perhaps 5°) with a new thermoelement, by simply calibrating it at, say, two points such as silver and diopside, and thus locating it among the family of deviation-curves.

5. *Relation of Thermal E.M.F. to Composition.*

In the course of the work on the nitrogen thermometer, the standard 10 per cent elements were compared with elements whose alloy wires contained 1 per cent and 15 per cent rhodium. The e.m.f. of the 20 per cent alloy, of which the bulb was made, was determined by two methods,* for the purpose of evaluating the differential readings on the nitrogen thermometer bulb. To make the series more complete, a 5 per cent alloy was obtained from Heraeus and its readings against pure platinum were compared with the standards.

A similar series of comparisons was made in 1892 by Holborn and Wien,† using alloys with 9, 10, 11, 15, 20, 30, 40, and 100 per cent rhodium. This work was done, however, just at the beginning of the careful work of Mylius on the separation of the platinum metals, and the alloys then available were not pure. In the lower percentage alloys, different elements of the same nominal composition gave e.m.f.'s differing by 10 per cent or more, and varying differently with temperature. In the higher percentages, the e.m.f. varies little with the composition, and the results have therefore

* Day and Sosman, loc. cit., p. 119.

† L. Holborn and W. Wien, Über die Messung hoher Temperaturen. Ann. Phys., xlvii, 107-134, 1892.

TABLE II.—STANDARD CURVE OF ELEMENT Pt: (90 Pt 10 Rh) FROM 0° TO 1755°.

<i>t</i>	<i>e</i>	Diff.	<i>t</i>	<i>e</i>	Diff.	<i>t</i>	<i>e</i>	Diff.
0			300	2315		580	5026	
10	55	55	305.4 Benzo.	2365	92	590	5127	101
20	112	57	310	2407		600	5229	102
30	172	60	320	2500	93	610	5331	102
40	234	62	320.2 Cd	2502	93	620	5434	103
50	297	63	330	2593		629.2 Sb	5529	103
60	362	65	340	2687	93	630	5537	
70	429	67	350	2781	94	640	5640	103
80	498	69	360	2875	94	650	5744	104
90	569	71	370	2969	94	660	5848	104
100	641	72	380	3064	95	670	5952	104
110	714	73	390	3159	95	680	6056	104
120	789	75	400	3254	95	690	6161	105
130	866	77	410	3350	96	700	6266	105
140	944	78	418.2 Zn	3429	96	710	6371	105
150	1023	79	420	3446		720	6477	106
160	1103	80	430	3542	96	730	6583	106
170	1184	81	440	3639	97	740	6689	106
180	1266	82	450	3736	97	750	6795	107
190	1349	83	460	3833	97	760	6902	107
200	1433	84	470	3931	98	770	7009	107
210	1518	85	480	4029	98	780	7117	108
217.7 Napht.	1584		490	4127	98	790	7225	108
220	1604	86	500	4226	99	800	7333	108
230	1690	86	510	4325	99	810	7441	108
240	1777	87	520	4424	99	820	7550	109
250	1865	88	530	4524	100	830	7659	109
260	1954	89	540	4624	100	840	7769	110
270	2043	89	550	4724	100	850	7879	110
280	2133	90	560	4824	100	860	7989	110
290	2224	91	570	4925	101	870	8100	111
		91			101			111

TABLE II.—STANDARD CURVE OF ELEMENT PT: (90 Pt 10 Rh) FROM 0° TO 1755°.—*Concluded.*

<i>t</i>	<i>e</i>	Diff.	<i>t</i>	<i>e</i>	Diff.	<i>t</i>	<i>e</i>	Diff.
880	8211		1170	11572		1470	15183	
890	8322	111	1180	11692	120	1480	15304	121
900	8434	112	1190	11812	120	1489.8	<i>Co</i> 15423	121
910	8546	112	1200	11932	120	1490	15425	
920	8658	113	1210	12052	120	1500	15546	121
930	8771	113	1220	12172	120	1510	15666	120
940	8884	113	1230	12292	120	1520	15787	121
950	8997	114	1240	12412	120	1530	15908	121
960	9111	114	1250	12532	120	1540	16029	121
960.0	<i>Ag</i> 9111		1260	12652	120	1549.2	<i>Pd</i> 16140	121
970	9225	114	1270	12772	120	1550	16150	
980	9339	115	1280	12892	120	1560	16270	120
990	9454	115	1290	13012	120	1570	16491	121
1000	9569	116	1300	13132	120	1580	16512	121
1010	9685	116	1310	13252	120	1590	16632	120
1020	9801	116	1320	13372	120	1600	16753	121
1030	9917	117	1330	13492	120	1610	16873	120
1040	10034	117	1340	13612	121	1620	17093	120
1050	10151	117	1350	13733	121	1630	17113	120
1060	10268	118	1360	13854	121	1640	17233	120
1062.4	<i>Au</i> 10296		1370	13975	120	1650	17353	120
1070	10386	118	1380	14095	121	1660	17473	120
1080	10504	118	1390	14216	121	1670	17593	120
1082.6	<i>Cu</i> 10535		1391.2	<i>Diops.</i> 14231		1680	17713	120
1090	10622	118	1400	14337	121	1690	17833	120
1100	10740	118	1410	14458	121	1700	17953	120
1110	10858	119	1420	14579	120	1710	18073	120
1120	10977	119	1430	14699	121	1720	18193	120
1130	11096	119	1440	14820	121	1730	18313	120
1140	11215	119	1450	14941	121	1740	18433	120
1150	11334	119	1452.3	<i>Ni</i> 14969		1750	18553	120
1160	11453	119	1460	15062	121	1755	<i>Pt</i> 18613	

some value in indicating the course of the curve of e.m.f. and composition. The data have been corrected to our temperature scale, and also for the difference in e.m.f. standards.

Holborn and Day* in 1899 obtained the e.m.f. of pure platinum against two samples of pure rhodium up to 1300°. The data have been corrected to correspond to our temperature scale.

Waidner and Burgess† measured the e.m.f. of the 10 per cent against the 20 per cent alloy, using two samples, at various points up to 1755°. The addition of this value to the e.m.f. of the 10 per cent alloy against pure platinum gives an independent check on our direct measurements with the 20 per cent alloy. As appears on the curves in fig. 4, the agreement is very good.

TABLE III.—THERMAL E.M.F. OF PURE PLATINUM AGAINST PLATINUM-RHODIUM ALLOYS, IN MILLIVOLTS.

t	1%	5%	10%			15%	20%	30%‡	40%‡	100%§
			Low	High	Standard					
100°	0.21	0.55	0.63	0.64	0.64	0.65	----	----	----	0.65
200	0.42	1.18	1.41	1.43	1.43	1.50	----	----	----	1.51
300	0.63	1.85	2.28	2.32	2.32	2.41	----	2.34	2.45	2.57
400	0.84	2.53	3.21	3.26	3.25	3.45	3.50	3.50	3.64	3.76
500	1.05	3.22	4.17	4.23	4.23	4.55	4.60	4.74	4.93	5.08
600	1.25	3.92	5.16	5.24	5.23	5.71	5.83	6.06	6.31	6.55
700	1.45	4.62	6.19	6.28	6.27	6.94	7.18	7.49	7.80	8.14
800	1.65	5.33	7.25	7.35	7.33	8.23	8.60	9.01	9.37	9.87
900	1.85	6.05	8.35	8.46	8.43	9.57	10.09	10.67	11.09	11.74
1000	2.05	6.79	9.47	9.60	9.57	10.96	11.65	12.42	12.94	13.74
1100	2.25	7.53	10.64	10.77	10.74	12.40	13.29	14.33	14.99	15.87
1200	2.45	8.29	11.82	11.97	11.93	13.87	14.96	16.39	17.13	18.10
1300	2.65	9.06	13.02	13.18	13.13	15.38	16.65	18.51	19.51	20.46
1400	2.86	9.82	14.22	14.39	14.34	16.89	18.39	20.67	21.73	----
1500	3.06	10.56	15.43	15.61	15.55	18.41	20.15	----	----	----
1600	3.26	11.31	16.63	16.82	16.75	19.94	21.90	----	----	----
1700	3.46	12.05	17.83	18.03	17.95	21.47	23.65	----	----	----
1755	3.56	12.44	18.49	18.70	18.61	22.31	24.55	----	----	----

The summarized data are given in Table III. For the 10 per cent alloy three values are given: first, the lowest-reading of the twelve elements used with the nitrogen thermometer; second, the highest-reading; and third, the standard element E.

The frequent comparisons of the platinum and rhodium wires of the standard 10 per cent elements during the work on the nitrogen thermometer, show that the differences among

* Thermoelectricity in Certain Metals, this Journal (4), viii, 303-8, 1899; Ann. Phys. (4), ii, 522, 1900; Sitzb. Berl. Akad., xxxvi, 691-5, 1899.

† Bur. Bull. Standards, iii, 200, 1907.

‡ Holborn and Wien, 1892, loc. cit.

§ Holborn and Day, mean value, 1899, loc. cit.

them are due partly to the platinum wire and partly to the alloy. Element Z, for instance, reads lower than E chiefly because the platinum wire of Z, is more impure than that of E; the effect of this impurity is partly neutralized by an apparently larger amount of rhodium in the alloy wire. This appears from the data in the table below, which show comparisons between several typical 10 per cent elements. The purest platinum appears to be that of J. If the thermoelectric effect of rhodium is proportional to its percentage from 0 to 1 per cent, then about 0.05 per cent rhodium in the platinum wire would be sufficient to produce the difference between Z and E. The data are in microvolts.

Element	E.M.F. of Pt wire against Pt of E at 1500°	E.M.F. of Rh wire against Rh of E at 1500°	Difference between elements
Y -----	+ 12	+ 75	+ 63
Z -----	+ 177	+ 67	- 110
A -----	+ 75	+ 47	- 28
F -----	+ 7	+ 1	- 6
J -----	- 9	+ 1	+ 10

The data of Table III are plotted in fig. 3, which shows the relation between temperature and thermal e.m.f. for various alloys. The 30 per cent and 40 per cent curves represent the data of Holborn and Wien. The curve for pure rhodium represents the mean of the two samples of Holborn and Day. There is no indication of a break in any of the curves, over the entire range of temperature.

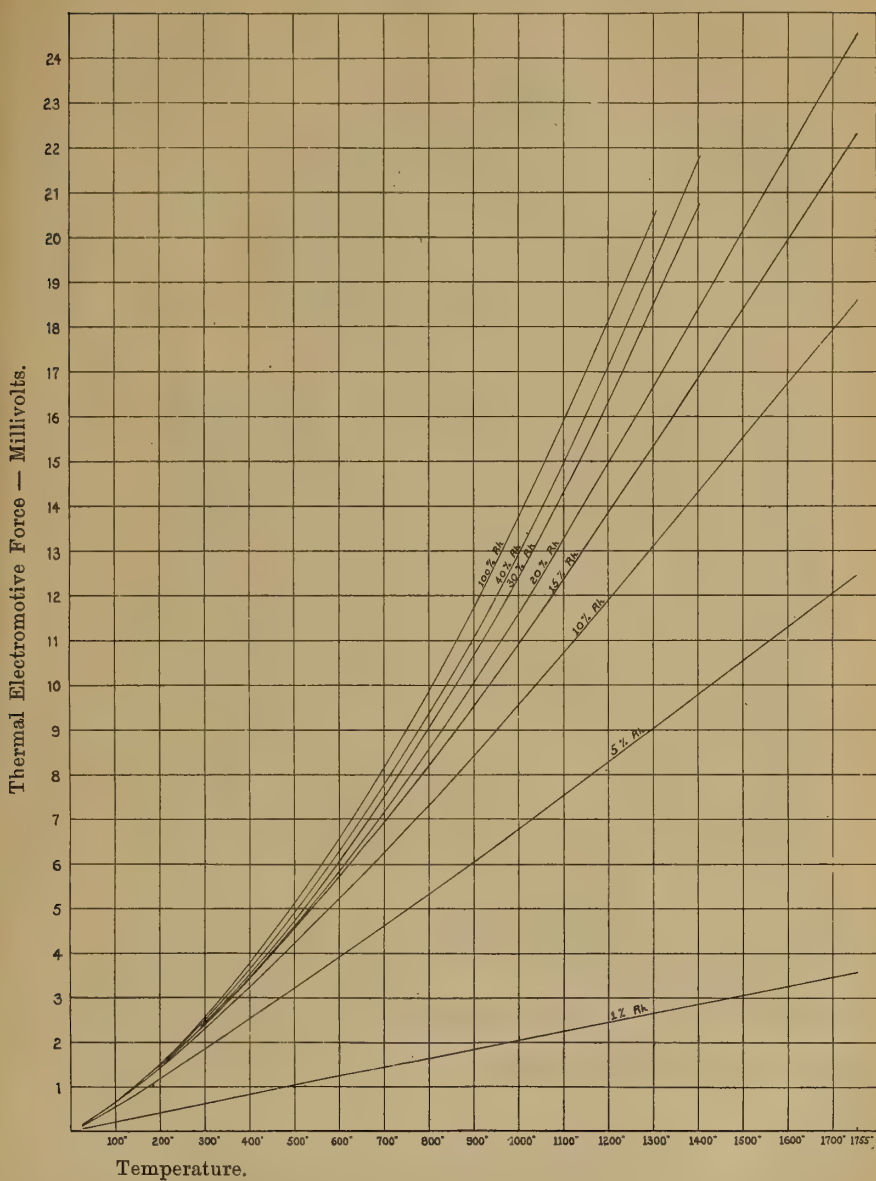
In fig. 4 the data of Table III are plotted to show the relation of the thermal e.m.f. at various constant temperatures to the composition of the alloy wire, the cold junction being in every case at 0°. At all temperatures the e.m.f. increases very rapidly with the first additions of rhodium, and at 20 per cent the value has already reached 81 to 93 per cent of the e.m.f. of platinum against pure rhodium.

The thermoelectric power, or rate of change of e.m.f. with temperature, $\frac{de}{dt}$, is plotted in fig. 5 against the atomic concentration of the alloy. The values are in microvolts, against pure platinum. The curves for all temperatures are similar in form and approach the curve for 1755° as an envelope.

In a recent study of the thermoelectric properties at low temperatures of the alloys of tellurium with antimony, tin, and bismuth, and of antimony with silver, Haken* comes to the conclusion that a thermoelectric curve of the form of those in fig. 5 accompanies the formation of a solid solution between the end components, while compounds are marked by sharp maxima or minima. The thermoelectric curves of the systems

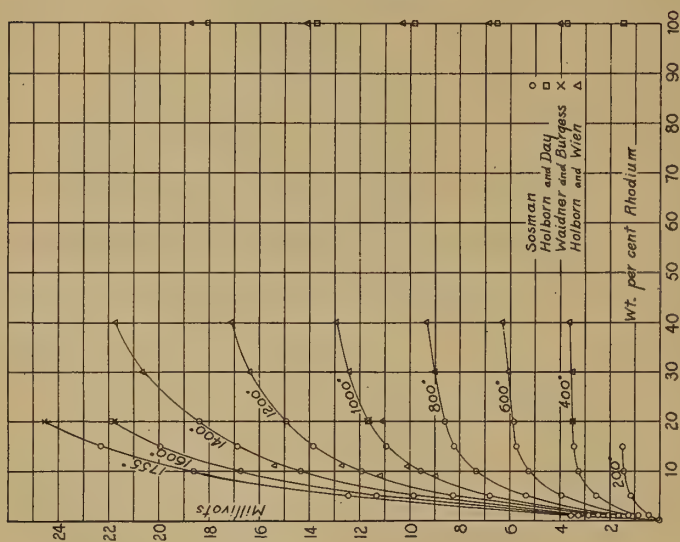
* Verh. Deutsch. Phys. Ges., xii, 229-39, 1910.

FIG. 3.



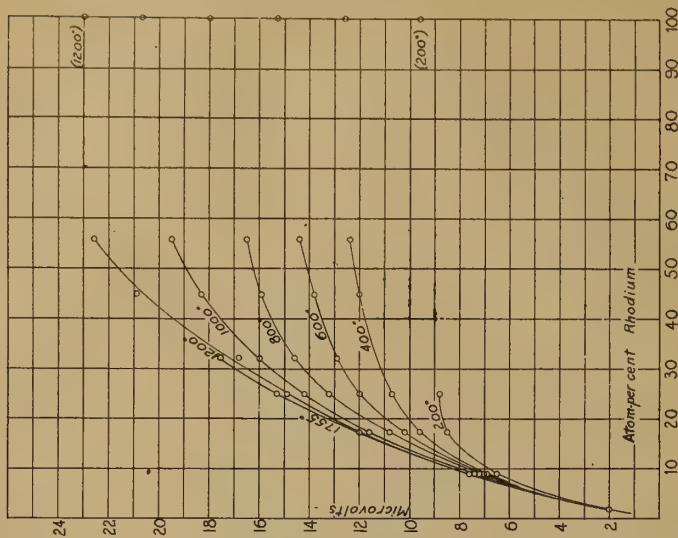
Relation of temperature to thermal electromotive force of platinum against platinum-rhodium alloys.

FIG. 4.



Relation of thermal electromotive force, e , to composition of platinum-rhodium alloys.

FIG. 5.



Relation of $\frac{de}{dt}$, thermoelectric power against platinum, to atomic composition.

copper-cobalt, by Reichardt;* copper-nickel, by Feussner and Lindeck;† and silver-zinc, by Puschin and Maximenko,‡ show a similar relationship between the form of the curve and the constitution of the alloy.

The alloys of platinum and rhodium have not been studied microscopically or thermally, but measurements in our carbon-tube furnace showed that the melting points of the 1 per cent and 5 per cent alloys are higher than 1755°. The melting point of the 10 per cent alloy is given by von Wartenberg§ as 1830°, and of pure rhodium as 1940°. It is very probable, therefore, that platinum and rhodium form solid solutions at least as far as 55 atomic per cent rhodium, with no compounds, over the range of temperature covered by the data.

6. Summary.

1. In continuation of the recent work from the Geophysical Laboratory on the nitrogen thermometer from zinc to palladium the interpolation curve of the thermoelement Pt: (90 Pt 10Rh) has been extended downward to 0° and upward to the melting point of platinum, 1755°. The standard scale of temperatures adopted is given on page 6.

2. The value of the melting point of platinum obtained by extrapolation of the curves of thermoelements with from 1 to 15 per cent rhodium confirms the value 1755° within the estimated limit of 5°.

3. A simple method of interpolating temperatures with the 10 per cent thermoelement by means of a standard curve (Table II, p. 9) and deviation curves (p. 7) is described.

4. The variation of thermal e.m.f. with the temperature and composition of the alloy wire is shown graphically in figs. 3 and 4, pages 13 and 14. The variation, both with temperature and with composition, is, within the limits of error, continuous over the entire range studied.

5. The variation of thermoelectric power, $\frac{de}{dt}$, with the temperature and composition of alloys of platinum and rhodium, is shown graphically in fig. 5, page 14. The data indicate the formation of solid solutions, but no compounds, from 0 to 55 atomic per cent of rhodium.

Geophysical Laboratory,
Carnegie Institution of Washington,
Washington, D. C., April 30, 1910.

* Ann. Phys. (4), vi, 832-55, 1901.

† Wiss. Abh. Phys.-Tech. Reichsanst., ii, 1895.

‡ Jour. Russ. Phys. Chem. Ges., xli, 500-524, 1909.

§ Verh. Deutsch. Phys. Ges., xii, 121-127, 1910.

ART. II.—*On some Remarkable Twins of Atacamite and on some other Copper Minerals from Collahurasi, Tarapaca, Chili; by W. E. FORD.*

SOME time ago a suite of copper minerals from Collahurasi, Chili, was presented to the Brush Collection by Mr. Ernest Schernikow of New York City. They included the following rare species: atacamite, brochantite, olivenite, clinoclasite, and conichalcite. The atacamite and the brochantite occurred in crystals and in considerable quantity, so that they offered excellent opportunities for investigation.

Atacamite.—This mineral was found in crystalline masses made up for the most part of quite small crystals, but at times

FIG. 1.

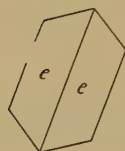


FIG. 2.

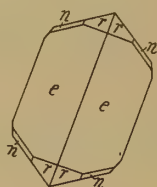
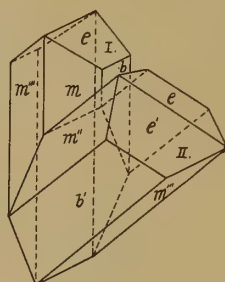
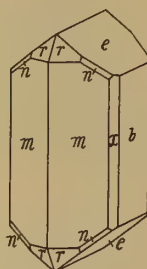
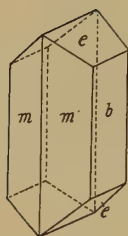


FIG. 3.

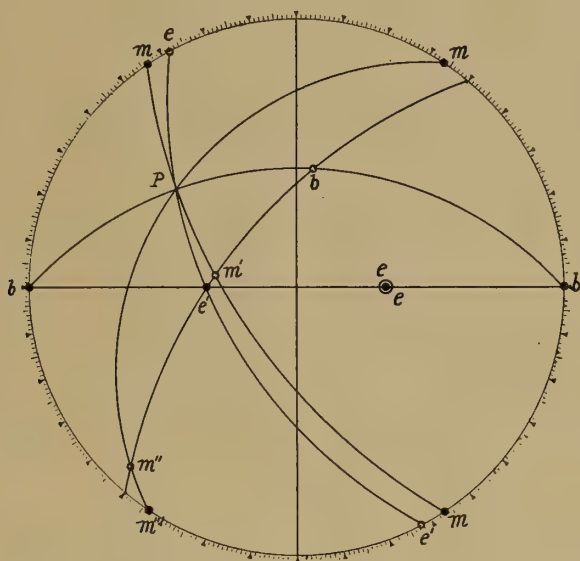


showing individuals four or five millimeters in length. These crystals on examination proved to be unusually interesting. The forms present were few, being m (110), x (140), b (010), e (011), r (111) and n (121). The majority of the crystals showed only the brachypinacoid, unit prism, and dome, illustrated in figure 1. The pyramids r and n and the prism x were only observed on a few individuals and then only as small truncations, as shown in figure 2. The interest in the crystals lay, however, in the constant and unusual twinning that they showed. The law of twinning is new to atacamite and in some ways proved very puzzling and difficult to explain, but

the close agreement between the measured and calculated angles, as shown in the tables below, leaves no doubt that it has at least been correctly formulated.

The law of twinning may be stated as follows: One of the e planes of the twin individual is always parallel to one of the e faces of the individual in normal position. This is readily seen on inspection of the crystals, for one brachydome face of the twin always "flashes" with one of the dome faces of the normal individual. Further, the twinned individual has been turned on the pole to $e(011)$ as if on a twinning axis through such an angle that the second e face of the twin falls in the prism zone of the crystal in normal position. These relations can be best explained by use of figure 3, drawn, not from a

FIG. 4.



crystal, but rather to illustrate the law. Face e of the crystal in twin position (No. II) is parallel to e of the individual in normal position (No. I), while e' of No. II falls in the same zone as the prism and pinacoid faces of the vertical crystal. These facts were proven when the twin crystals were placed upon the reflection goniometer. The signals from the e faces of the two individuals coincided with each other, and the signal from e' of No. II fell in the same zone as the prism faces of No. I. This was found to be true on all the crystals measured, with only such slight variations as the occasional rather

indifferent quality of the faces could easily account for. The relations existing between the two individuals is shown in the stereographic projection, figure 4.

In order to bring the two individuals into their respective positions, i. e., e' of No. II into the prism zone of No. I, we have to conceive of individual No. II as being turned about the pole of $e(011)$ as an axis through an arc of $112^\circ 40'$. This is the fact that makes these twins unusual and difficult to explain. The arc of revolution of a twin crystal about a twinning axis is usually 180° or sometimes 120° . On account of this peculiarity we cannot consider, at least in the usual sense, either the plane e , although it is common to the two individuals, as a twinning plane nor its pole as a twinning axis. The plane whose pole is lettered P on the stereographic projection, and which is shown as the plane of junction of the two individuals in figure 3, would answer to the ordinary definition for a twinning plane. The twinned half of the crystal could be obtained from the normal half by reflection over this plane, as is shown in the stereographic projection, for upon a great circle drawn from any face of individual No I through the pole P will be found at an equal angular distance on the other side of P, the corresponding face of the twinned individual, No. II. But this plane P does not correspond in its position to any crystal face on atacamite, falling nearest to the possible pyramid ($\bar{4}75$). The proof of the law of twinning as stated lies in the following tables of measured and calculated angles. The crystals were measured on both the two-circle and one-circle goniometers, the angles obtained on each being given.

1. Angles measured on the two-circle goniometer giving the position of the faces of the twin individual.

Faces of No. II	Measured				Calculated		
	ϕ	Average	ρ	Average	ϕ	ρ	
e			$36^\circ 58'*$	$36^\circ 50'$	$0^\circ 0'$	$36^\circ 55\frac{1}{2}'$	
			$36^\circ 50$				
			$37^\circ 16$				
			$36^\circ 45$				
			$36^\circ 24$				
e'	$62^\circ 29'*$	$62^\circ 46'$	$90^\circ 1'*$	$90^\circ 6'$	$62^\circ 25'$	$90^\circ 0'$	
	$63^\circ 1$		$90^\circ 38$				
	$62^\circ 12$		$90^\circ 21$				
	$63^\circ 22$		$89^\circ 24$				
m	$8^\circ 59'*$	$10^\circ 20'$	$34^\circ 31'*$	$33^\circ 24'$	$8^\circ 47'$	$33^\circ 57'$	
	$8^\circ 44$		$31^\circ 44$				
	$11^\circ 38$		$34^\circ 1$				
	$12^\circ 1$		$33^\circ 21$				

Faces of No. II	Measured				Calculated	
	ϕ	Average	ρ	Average	ϕ	ρ
m'	47° 45'*	46° 31'	83° 56'*	83° 49'	47° 1½'	84° 31'
	47 38		84 8			
	45 25		83 46			
	46 20		82 58			
	46 31		85 2			
	46 3		84 54			
	46 12		84 2			
b	80° 48'*	80° 29'	48° 35'	47° 51'	81° 9'	48° 17'
	80° 9'		47° 7'			

2. Angles measured on a one-circle goniometer between faces of individuals I and II.

	Measured	Average	Calculated
e' of No. I $\wedge$ e' of No. II	106° 24' } 105 54 } 106 23 } 106 3 }	106° 11'	106° 10'
m of No. I $\wedge$ e' of No. II	5° 44' } 6 20 } 5 54 } 5 36 }		
m''' of No. I $\wedge$ m'' of No. II	10° 39' } 11 17 } 10 42 } 11 17 }	11° 1'	10° 57'
m of No. I $\wedge$ m'' of No. II	67° 56½' } 68 1 }		
m''' of No. I $\wedge$ m' of No. II	76° 56 } 76 6 } 76 59 } 76 50 }	76° 42'	76° 29'

The above tables give all the measured angles on the different crystals without regard to the quality of the faces and the consequent authority of the angles. In general, however, the average values of the angles of the different series are reasonably close to the calculated angles. In the case of the table of the measurements made on the two-circle goniometer the angle, derived from the measurement of the best crystal and the one which permitted of the most accurate adjustment on the goniometer, is given first in each list and is further marked by an asterisk. The agreement between these angles and the corresponding theoretical values is quite close. The widest variation between the measured and the calculated angles is to be found in the case of the faces in the prism zone, and with

these faces particularly in the case of the ϕ angles. This is a result to be expected from the usual rather poor quality of the prism faces and from the fact that they are frequently vertically striated.

It will be noticed that in the case of the one-circle goniometer measurements the agreement between the measured and the calculated angles is much closer and in general is very satisfactory. This is as would be expected, since with these small crystals having not the best of faces the adjustment of a crystal upon the two-circle goniometer is difficult and can only be approximate at the best, and consequently the angles measured upon it have not as great an authority as those made upon the one-circle instrument where the adjustment is made for each measurement. Considering, however, all the measurements, their agreement with the theoretical angles is sufficiently exact to prove without doubt that the law of twinning has been correctly stated.

The author does not know of any case of twinning strictly analogous to the one outlined above, and he does not offer any elaborate explanation or theory to account for the peculiarities shown by these twins. An interesting and probably significant fact is that, when in twin position, the faces of individual No. II lie for the most part within a few degrees, at least, of the faces of the normal individual, No. I. This is clearly brought out in the stereographic projection, figure 4, where e' of No. II lies near m of No. I; m'' of II near m''' of I; m' of II near e' of I; and b' of II falls near the macrodome zone of I. It would seem here as if we had a case of twinning in which the position of the twin individual was controlled rather by parallelism of a prominent face and by zonal relations between the two individuals than by the presence of a common twinning plane or axis. The plane P, which if a possible crystal plane would be considered as the twinning plane, may be regarded as a composition or accommodation plane similar in a way to the rhombic section found in the plagioclase feldspars when they twin according to the pericline law.

That all regular intergrowths of crystals do not obey the ordinary laws of twinning has been recognized for some time.* These intergrowths are not accidental in character, but obey laws that can be definitely formulated; they are to be found repeatedly on different specimens and must be included in any complete discussion of twinning. Goldschmidt has recently attempted to include these unusual intergrowths in a new classification of twins and has given various names to the new groups he has formed, such as "Heterozwillinge," "Ein-

* See Goldschmidt, Zs. Kr. xxx, 254, 1898; xliii, 347, 1907.

flächige Verwachsung," "Einzonige Verwachsung."* It is to be expected, as attention is called to these twins of lower symmetry, that more examples will be discovered and still other groups formed. In fact the twins described in this paper do not seem to exactly fit into any of the groups in Goldschmidt's scheme, resembling most nearly, however, his group of "hetero-twins." A hetero-twin of orthoclase recently described by Paul and Goldschmidt† is in some respects similar to these twins of atacamite. The law governing the orthoclase twin is stated as follows: the face $c(001)$ of No. II is parallel with $b(010)$ of No. I; the zone $c(001)-m(110)$ of No. II corresponds with zone $b(010)-c(001)$ of No. I, and face $b(010)$ of No. II falls in the zone $c(001)-y(201)$ of No. 1. Here we have in the two individuals a parallelism of two unlike faces, two unlike zones falling together and a prominent face of one individual falling in a prominent zone of the other. In the case of the atacamite twins we have, on the other hand, two similar faces in parallel position and a prominent face on No. II lying in a prominent zone of No. I, and in general the faces of No. II lying near to faces or zones of No. I.

FIG. 5.

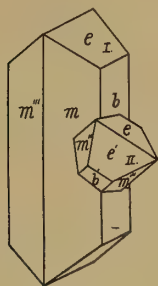


FIG. 6.

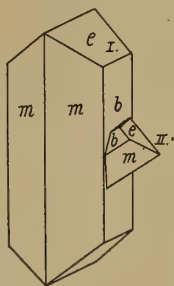
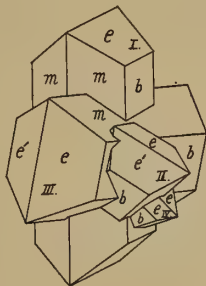


FIG. 7.



The twin crystals are of two types. The first, which is illustrated in figures 5 to 7, is of an interpenetration type where one individual grows through another or projects from it. Usually in this type one individual is much larger than the other, and the smaller is seen in the group of faces at one of its ends projecting from the side of the first. Such a crystal is shown in figure 5. Of such an intergrowth there can be two sorts, depending upon whether the twin individual has been turned toward the front or the back of the one in normal position. Figure 6 shows such a twin with No. II projecting from the back of No. I. These twins appear sometimes in very complex groups, one individual being twinned upon the first, a third being in twin position in regard to the second, etc. Such

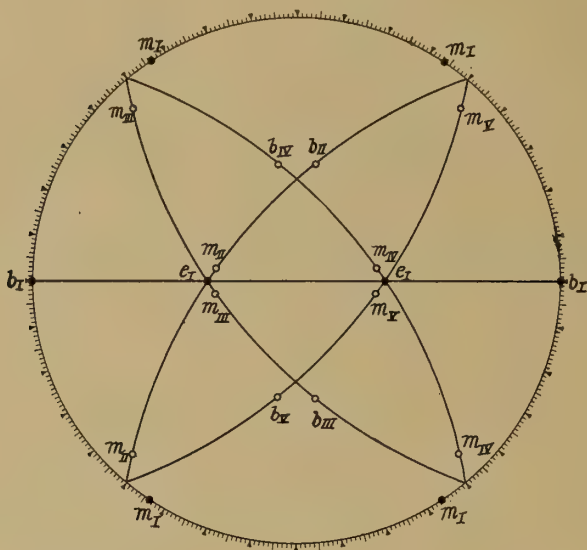
* Zs. Kr., xliii, 582, 1907.

† Zs. Kr., xlv, 471, 1909.

a complex group is represented in figure 7, No. II being in twin position in respect to No. I, while No. III is in twin position in respect to No. II, e of III being parallel to e' of II, etc.

The second type of twin crystals, although governed by the same law, is very different in habit. It consists of a normal individual having a rather stout development, with its dome faces

FIG. 8.



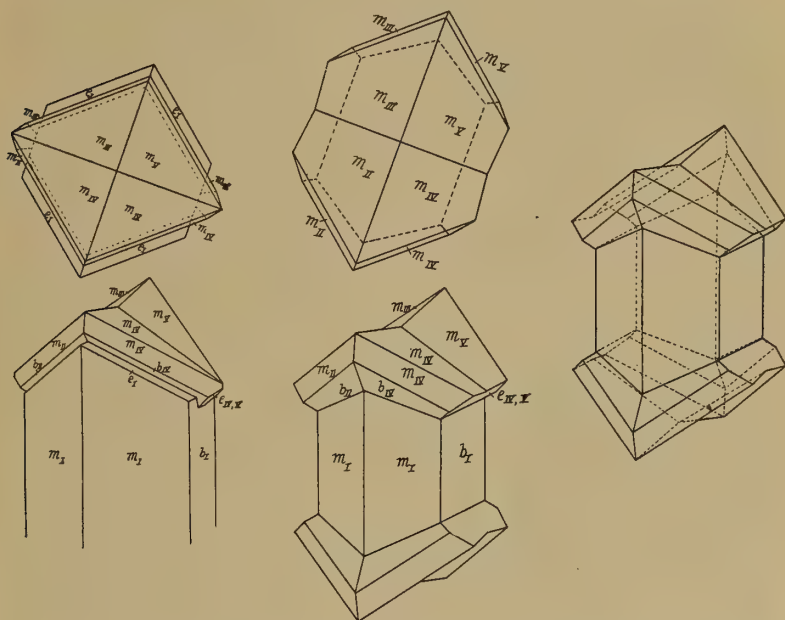
at either end nearly if not entirely covered by four individuals in twin position. Two of these twin individuals have one of their e faces parallel to one of the planes of the crystal in normal position, one twin being revolved toward the front and the other toward the back. The other two twin individuals have a similar relationship and arrangement except one of their e faces is parallel to the second e face of the normal crystal. These twinned individuals usually show only the faces of the prism and the brachypinacoid, which, lying on the top of the normal crystal, form shallow troughs running in the direction of the brachy-axis on either side above the position of its dome faces. Occasionally e faces of the twins are found either at the side forming a projection over $b(010)$ of the normal crystal or sometimes in slight reëntrant angles along the crest of the crystal. These relations are shown on the stereographic projection, figure 8, which gives the forms of the crystal in normal position and the prism and pinacoid faces of the four different twin posi-

tions, II, III, IV, and V. A crystal of this type is illustrated in figure 9, where the four twin individuals do not entirely cover up the dome faces of the normal crystal. This figure also shows the e face common to twins IV and V above the b face of the normal crystal. At times the faces in twin position completely envelope the ends of the normal crystal, allowing only the faces of its prism zone to show. A doubly terminated crystal of this type is shown in figure 10. Figure 11 is the same as figure 10 with the lines of the back faces showing in order to assist in forming a mental picture of these strange twin groups. In addition to groups such as figured there are much more complicated ones in which both types of twins are found with bewildering relations to each other.

FIG. 9.

FIG. 10.

FIG. 11.



An analysis was made of the atacamite crystals which agreed closely with the theoretical composition of the mineral as shown below.

		Theory
Cl	16.55	16.6
Cu	14.82	14.9
CuO	56.01	55.8
H ₂ O	12.69	12.7
Total	100.07	100.0

Brochantite.—Brochantite was the most common mineral observed on the specimens. It occurs generally in slender prismatic crystals that interlace and cross each other to form granular crystalline masses. Occasionally a crystal with good faces was observed that could be measured. The following forms were identified: $b(010)$, $m(110)$, $r(120)$, and $v(101)$, and their characteristic development is shown in figure 12. In addition to this type of occurrence, brochantite was observed in very slender, almost capillary, prisms arranged in radiating tufts on the surface of the gangue material. With its transparent, bright green color, this variety makes very striking and beautiful specimens. A quantitative analysis of these slender crystals was carried far enough to establish their identity with brochantite. An analysis of the type of material first described was carried to completion. The material analyzed was of ideal purity, and the results agree very closely with the theoretical values. The results of the analysis follow:

FIG. 12.



	I	II	Average	Theory
CuO	70.41	70.16	70.29	70.37
SO ₃	17.51	17.59	17.54	17.69
H ₂ O	11.91	12.01	11.96	11.94
			99.79	100.00

Olivenite occurs on the specimens as slender to acicular prismatic crystals of light to dark olive-green color. The mineral gave the appropriate tests for olivenite, and one crystal was found which had terminal planes sufficiently good to permit of decisive measurements being made. The prism zone of the crystals was always deeply striated, and terminal planes were only rarely observed.

Clinoclasite was observed on only a few specimens, and then in microscopic crystals. It was identified by its blue-black color and the blowpipe tests that it gave. Conichalcite was found very sparingly in the characteristic emerald-green globular form. Other copper minerals in small amount were observed, some of which could not be positively identified with any known species but which occurred in too small an amount to permit of investigation.

ART. III.—*Crustal Warping in the Temagami-Temiskaming District, Ontario*; by L. V. PIRSSON.*

THE gradual rising of the great Ontarian shield, upon whose southwestern flank the great lakes are being slowly tilted to the southwestward, presents a geologic problem of primary importance. We may reasonably expect that fuller knowledge concerning it will throw much light on secular continental movements.

This tilting and the various phenomena to which it has given rise have been the subjects of study by various geologists, particularly Gilbert and Taylor, whose results have been published in a notable series of articles. The latter has especially studied the sequence of events arising along the north shores of the Great Lakes from their southward canting, and, in his paper on the former Lake Algonquin stage of the lake system, he presents a map upon which the node lines, or axes of tilting, are given.† It is of great importance that this work should be carried to the northward, and especially to the northeast, so that ultimately the crest and extent of the rising shield may be determined. So far not much work in this direction has been undertaken with this object in view, and in this brief paper the writer desires to point out a region whose topographic features appear to offer much of interest and significance in connection with this matter. His attention was first called to it in the summer of 1907, on a visit to the mining region of Cobalt, during which Lake Temagami was traversed and Lake Temiskaming and the Ottawa valley descended. No detailed studies were carried out, but the observations made en route on journeys lasting a couple of weeks in this area aroused his interest in it, and this has been deepened by a study of what has been written upon it, and especially by the excellent report and geologic maps of Barlow‡ and of the Provincial geologists on the mining district. The facts given in this article are taken mostly from these sources, supplemented in a few cases by original observations.

Lake Temiskaming.—This lake is nearly 70 miles long from the point where the River des Quinzes enters it to the outlet at the head of the Long Sault Rapids. While in the upper portion it is several miles wide, this width soon diminishes and the greater part of the lower portion is not over a mile broad, or is even less; in some stretches it is not wider than the Ottawa River to which it gives rise. There is a difference of water

* Abstract of a paper given before the Yale Geological Club, April, 1909.

† F. B. Taylor, Amer. Geol., vol. xv, p. 116, 1895.

‡ Ann. Rep. Geol. Surv. of Can., vol. x, 1897, Rep. I.

level between the head and foot, at times, of one or two feet and this gives a distinct current through the lake, which at the narrower constrictions becomes quite pronounced. The general direction of the lake is south-southeast. While the upper part of the valley occupied by the lake is more open, the greater part, where the lake is narrow, is a deep trench cut in the gneisses of the old upland. Thus from the shores rise

FIG. 1.



Drainage map of the Temagami-Temiskaming Region.

abruptly bold rocky hills with heights ranging from 350 to 600 feet, which in many places pass into towering cliffs. Thus the aspect of the lake is like that of a fiord, and it is in truth a miniature Saguenay. At the same time, considering its narrowness, the lake is remarkably deep. From the Opemika Narrows at the point marked A on the map, Barlow found that the depth gradually increased until it reached 470 feet near the mouth of the Kipiwa* River. This is near the middle of

* This name is spelled in a variety of ways; even on the same official map more than one appears. The spelling selected seems the simplest and to express the sounds as the inhabitants pronounce it; the writer, however, disclaims any attempt to fix usage.

the lake; from here it gradually shallows and opposite the mouth of Montreal River is 350 feet deep. At the point B on the map, old Fort Narrows, there is a very marked contraction, owing to a heavy deposit of sand and gravel in the trench at this place. The depth on this is perhaps 50 feet and the lake again deepens to the north but does not reach the great depths of the lower part. It is also to be noted that where these great depths were obtained it was not only in the middle of the channel but close up to either shore.

From what has been stated it will be seen that the total depth of the trench, or rather canyon occupied by the lake, from the surface of the old upland to the lake bottom, is about 1000 feet at the deepest point, shallowing gradually either way, north and south. At the deepest point the former canyon is about one-half filled with water.

What is the origin of this lake? For one of its size and nature in this region three possibilities present themselves: it may be a rock basin cut by the ice sheet; it may be a river valley dammed by glacial drift, or it may be a warped valley. In regard to the first, since the general direction of flow of the ice sheet was toward the southwest or more accurately S. 14° W., as given by Barlow, it is inconceivable that it could have cut such a deep and narrow gorge transverse to its direction of flow. Barlow's list of glacial striæ shows, as might be expected, that in the upper, wider portion of the lake valley the topography exercised enough control to produce an undercurrent in the ice, trending to the southeast. As the valley contracts this becomes less evident and the western bank, with striæ in the direction of southwest flow, shows it was receiving the impact of the general moving ice sheet. In such a narrow, constricted gorge the local sub-current might be expected to die out, the trench would become packed with nearly motionless ice, up to the average level of the plateau, which would support the ice-sheet moving transversely across it. It seems improbable, therefore, not only that the basin was cut by the ice, but even that the pre-glacial valley was to any great extent deepened by its scour. The general appearance of the gorge, and the lack of truncated spurs, seems also to indicate no great amount of glacial control of its topography. It probably existed pretty much as it is to-day before the advent of the continental ice-sheet.

The explanation of a morainal dam also seems improbable when one considers the depth of the lake, the fact that the deepest part is not near the outlet but near the middle, and the character of the river bed below the outlet. There is no direct evidence of such a dam, and, as Barlow* remarks of the river

* Loc. cit. p. 171.

bed below the outlet: "Very little rock *in situ* can now be seen, although it is evident from the topography that the detritus was deposited in a pre-existing shallow narrows." Even were it admitted that the valley was dammed with glacial drift to a depth of 500 feet at this point, there would still be a rock barrier at the Mountain Rapids at the foot of the next stretch of still water, known as Seven League Lake, whose surface is about 50 feet lower than that of the main lake above, and which discharges down a rapids obstructed by rocky reefs and islets. Thus, even if a morainal dam exists of the great depth postulated, it can only be regarded as a secondary affair, forming a sort of facing on the downward slope toward the lake center of the bed-rock barrier beneath and giving at the most a height of some extra 50 feet to the lake.

It is not intended, of course, to deny in this that morainal deposits may not lie on the floor of the old canyon. They probably do, and the real rock floor may lie considerably deeper than the present bottom of the lake. At old Fort Narrows (B, on map) the gorge in large part is filled with a glacial deposit nearly choking the pre-existing narrows at this point. This very probably represents material accumulated by the local southeastward sub-glacial current in the ice which would be checked at this point. Only, as Barlow remarks, it could not have been originally much greater than it is now since on the down-stream side it slopes off with great sharpness to the depths of the lake. If it once projected somewhat above the present lake surface it was rapidly cut away until a grade was established between the two parts of the lake, and since then no great change in it has occurred.

The first two hypotheses of lake origin having been considered and dismissed there remains the third, and it now seems fairly evident that the lake represents a pre-glacial canyon which, by down-warping in its middle part, has become flooded. The total amount of down warp may be roughly estimated to be as much as 500 feet in the center of a distance of 50 miles in a general north to northwest and south to southeast direction.

Lake Kipiwa.—If such down-warping has occurred, it can scarcely be supposed that the immediate region would not be affected by it and the other drainages and lakes should show evidences of it. While not enough is known of those geologic features of the area which would offer decisive evidence on this point, there are some facts which appear to favor it. Thus Lake Kipiwa is so near to Lake Temiskaming and parallels it for such a distance that it should also be affected. It has not been seen by the writer, but Barlow describes it as filling several valleys parallel in a general way to Lake Temiskaming. These, like Temiskaming, cut across the general direction of

foliation of the gneissic rocks. The depth of the lake is not known. It has at present two outlets, the natural one by the Kipiwa River at the north end, and an artificial one produced by a dam at the outlet of the lake into the Kipiwa river and by the blasting away of the crest of a low rocky barrier by the lumbermen which causes the lake to discharge by Gordon's Creek into Temiskaming at the point marked "Outlet" on the map. Thus it would appear as if the canting of the lake to the north by the down warp had left the old outlet dry and caused it to seek a new one by the Kipiwa River. The latter, as it enters Temiskaming, is a swift, foaming torrent which plunges down over the rocks into the main lake at a point where the latter is nearly 400 feet deep, without entering through any distinct valley. As one sees it, it appears to have all the marks of topographic youth.

Lake Temagami.—This lake, some 40 miles to the west of Temiskaming, is also a many branched valley system which has been flooded and which discharges by two natural outlets, one at the north, the other at the south end. Neither of these has been seen by the writer, but from what he has been able to learn it is inferred that both are over rock rims. The greatest depth of the lake obtained by sounding near the central west shore is about 170 feet. The double outlet in connection with the warped character of the Temiskaming canyon is very suggestive, but since the direction of the axial line of the warped trough, as it would pass westward from Temiskaming, is not known, it may pass through Temagami Lake, or to the north, or south of it. In the first case the valley system would be flooded, and former water-work on shores near the central part would be drowned; if either of the latter two, the lake would have been canted north or south respectively and wave-work, such as beaches or sea-cliffs, would be elevated at the north or south ends. It should also not be forgotten that as the lake has many arms, some of them may have served as a former outlet and have been choked by a moraine dam which has caused the flooding and overflow elsewhere of the valley system. These are points which can only be settled by a careful study of its entire shore line, and it offers an attractive problem for investigation.

Drainage System.—In this connection attention is also directed to the remarkable drainage plan of the region (fig. 1). It is impossible to see it and avoid the conviction that there has been a distinct control in its production by rock structure. What is here evident on a small scale map is also striking on the large scale one of the mining district prepared by Miller.* This feature of the region has been previously commented

* 14th Ann. Rep. Bureau of Mines, Ontario, 1905.

upon. Bell,* in noting the course of Lake Temiskaming, suggests that it follows the course of a great dike which has been eroded; a suggestion which Barlow's geological map shows to be untenable. Hobbs,† in a short paper on fracture systems, briefly alludes to this drainage plan and gives a map of a part of the area showing its peculiar nature. He attributes it to joints. Miller‡ gives a more extended discussion of the systems of lines, and states that it is impossible to tell whether they follow faults or folds.

A study of Barlow's geologic maps of the Nipissing and Temiskaming sheets shows that these depressional lines of drainage are independent of the distribution of the rocks. The Montreal River, which holds a straight course through graywacke, slate, quartzite, and diabase, is a striking example of this. In a few cases, however, as plotted on the map, they appear to lie over the contact of formations. A consideration of the strike, especially of the planes of foliation of the gneissic areas, shows that they sometimes follow it, but just as often, and especially in the larger depressions, cut directly across it.

Either the drainage plan is directly conditioned by the present rock structures, or it is one that has been inherited; that is to say, it is superimposed upon the present surface by overlying formations, which once existed but have now disappeared. It is true that a remnant of an overlying formation, generally attributed to the Niagara, is found at the north end of Lake Temiskaming, but to restore this over the whole region would not only involve great improbabilities but would in itself give no explanation, for we should still have to account for the conditions in such an overlying series which would initiate such a drainage. It is also difficult to see how simple folding could produce such a rectangular net-work. On the whole, as suggested by Hobbs and Miller, it seems most probable that a system of nearly right-angled jointing and faulting has initiated planes of structural weakness through the region, which the streams have taken advantage of, and which has therefore exercised a directive control over them. While, as Miller remarks, it is difficult to directly prove this, since such lines of weakness in rock structure, or of displacement, are now for the most part covered by lakes, streams, and swamps, yet some corroborative evidence may be gleaned from Barlow's report where the jointed character of the rocks along the Montreal River is mentioned, and in one place of the direction of these joints as determining the course of the river.§ Many more such instances should be found when the region is more closely studied.

* Bull. Geol. Soc. America, vol. v, p. 365, 1894.

† Trans. Wisc. Acad. Sci., vol. xv, p. 19, 1905.

‡ Rep. of the Bureau of Mines, Ontario, vol. xvi, pt. ii, 1907, p. 36.

§ Loc. cit., p. 224.

If it be admitted that the drainage system is the outward revelation of an inward one of rock-fracturing, weakness, and probably to some extent displacement, then the network appears like the result of Daubrée's experiment on the induction of jointing by torsional warping.* It would seem natural to refer the lakes in part to minor warps or displacements of pre-existent channels along these lines of weakness, although in part they are probably due to morainal dams and to glacial scour.

Time of Warping.—If such warping with fracturing has taken place, the questions naturally arise as to when it occurred and if it is still continuing. The region has, as yet, not been studied in sufficient detail, with such questions in mind, to afford decisive answers. Some facts there are, however, which have a bearing on these points. Thus Miller† points out that the mineral veins follow closely the same systems as the water courses, and the deduction from this must follow that they are either contemporaneous or later than the formation of the fracture system. But the silver veins have been glaciated and consequently the fracture system is pre-glacial. Miller indeed refers it to post-middle Huronian time, this view being based on the hypothesis that the deposition of the ores was the result of the intrusions of diabase which are referred to this period. But inspection of the maps shows that the larger elements of the fracture systems, as indicated by the drainage lines, pass through these diabases as well as the older rocks. A careful study of the Niagara group, and especially of its contact with the older rocks, may throw much light on this question.

Whether the crustal movements here assumed continued after the glacial period and are still going on is a problem which demands further investigation. Miller‡ states that post-glacial faulting can be proved to have taken place. A noticeable feature of the region are the open torsion cracks and joints seen on glaciated rock-surfaces which have not been filled or eroded. They have been illustrated by Miller. While these are indications, more positive evidence would come, as has been previously suggested, from the canting of the lakes and exposures of uplifted beaches and marks of wave-work on shores. If such canting is pre-glacial these would be largely swept away, but if warping has continued into post-glacial times or been renewed, the evidence to prove it can undoubtedly be gathered.§

* *Géologie Expérimentale*, p. 510, 1879.

† *Loc. cit.*, p. 38.

‡ *Loc. cit.*, p. 38.

§ Since this paper was presented, and at the time of putting it in form for publication, the program of papers to be read at the Boston meeting of the Geol. Soc. Amer. has been received. In this is listed a paper by Dr. Robert Bell entitled the "Diversion of the Montreal River," and in the attending

Summary.—The ideas expressed in this paper may be now briefly summarized. That in this region there was first initiated by torsional warping in pre-glacial times a system of jointing, fracturing, and structural lines of rock weakness, and possibly foliation, which has controlled the drainages. That later, or continuing, warping has caused the beginning of a broad synclinal fold with the production of the larger lakes and other modifications of drainage; that this has taken place or continued into post-glacial times and may still be in progress, and that this is a minor feature of the uprise of the great Ontarian shield. It is not intended to assert that this idea or all parts of it are necessarily correct, or proven; only that the facts, so far as published and known, appear to point in this direction. For the object of this paper is not so much to state an hypothesis as to direct attention and to start an inquiry.

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New Haven, Conn.

short synopsis the view is advanced that the Montreal River in post-glacial times has been diverted from a former northward direction and made to flow southward by an uprise of the land which gives a southward tilt to its present course. This is in the region north of that covered by the map accompanying this article. While the writer has not heard this paper, this view, as thus stated, appears to favor the general idea expressed in this article and the southward flow of the river down the northern flank of the warp to be a local feature of the more general problem here presented.

ART. IV.—*The Jurassic Age of the "Jurassic Flora of Oregon";** by F. H. KNOWLTON.

INTRODUCTION.

THE stratigraphic and paleontologic relations of the earlier Mesozoic rocks of the Pacific Coast region, more particularly the Knoxville and related formations, have been the subject of prolonged investigation, and, it may be added, not a little difference of opinion as regards their interpretation. Mr. J. S. Diller, of the U. S. Geological Survey, is especially notable among those who have made this area the subject of study, and to his interest and energy we are principally indebted for the bringing to light of the numerous and often exhaustive collections of fossil plants. To Prof. Lester F. Ward and Prof. Wm. M. Fontaine we are also under obligation for the adequate study, illustration, and publication of these floras, without which they would, doubtless, have long remained unavailable for stratigraphic uses. Although the story told by the floras is seemingly plain and unequivocal, the conclusions of the paleobotanists have not always been given full consideration, and it is the object of the present paper to present this paleobotanical evidence in compact form, together with such stratigraphic and other paleontologic data as may be necessary to make the position clear.†

In November 1908, Mr. Diller published a paper under the title, "Strata containing the Jurassic Flora of Oregon,"‡ the thesis of which he sets forth as follows: "Two fossil floras have been reported from the Mesozoic rocks of California and Oregon, the one Cretaceous and the other Jurassic. With the former the fauna is Cretaceous, but with the latter the fauna has been regarded as a matter of doubt. It is the purpose of this paper to remove the doubt by showing that in parts of Oregon and California the Jurassic flora, . . . is in the 'Myrtle' and Knoxville beds, while elsewhere it extends down to the horizon of the Mariposa, and the general conclusion is reached that for the Pacific Coast the line between the Cretaceous and the Jurassic is the great unconformity at the base of the Knoxville."

The major portion of Mr. Diller's paper is devoted to proof that the Jurassic flora occurs in the Knoxville formation—a

* Published with the permission of the Director of the U. S. Geological Survey.

† The writer labors under the disadvantage of not having seen in the field the several formations here involved, and consequently the discussion is confined mainly to the paleobotanical evidence. The geological data are largely from Diller.

‡ Geol. Soc. Am., Bull., vol. xix, pp. 367-402, 1908.

in Douglas County; (3) along the forks of Elk River in Curry County. In California there are also three areas: (1) Big Bar and (2) Rattlesnake Creek in the Klamath Mountains, Trinity County, and (3) near Oroville, Butte County, the latter at the western base of the Sierra Nevada.

The Lower Cretaceous flora† is found along Iron Mountain Creek in the vicinity of Riddles, Douglas County, Oregon; at Redding Creek, Tehama County, California, and very extensively along the western side of the Sacramento Valley in Shasta and Tehama counties, California. The Jurassic and Lower Cretaceous floras, although occurring in the same areas, are perfectly distinct and have never been found commingled.

STRATIGRAPHIC RELATIONS OF THE BEDS CONTAINING THE "JURASSIC FLORA OF OREGON."

1. *Thompson Creek, Douglas County, Oregon.*

The beds exposed along Thompson Creek are 1000 feet or more in thickness and dip westward at an angle of about 38°. The lower three-fourths of the section is composed of conglomerates, with small local beds of sandstones and shale, while the upper third is made up of sandstone and shale. Although plant fragments are found at various points in the conglomeratic portion, the principal plant beds are in shaly sandstone about 180 feet below the top of the exposed Mesozoic section. This is one of the richest of the Jurassic plant localities, having furnished 66 species (see pp. 43-45).

As regards the invertebrates found at this locality Mr. Diller says:* "Shells are of exceptional occurrence in the leaf beds. Though carefully sought for, they have rarely been found. A doubtful fragment found with the plant fossils in Thompson Creek was referred to Doctor Stanton, who reported that "the fragment seems to be part of a shell and is probably an Aucella, although there is not enough of it for positive identification."

2. *Buck Peak, Douglas County, Oregon.*

On the northeastern side of Buck Peak, 1,200 feet below the summit, there is an important plant locality which is really embraced in the Thompson Creek area already considered.

* The flora, called in this paper the "Lower Cretaceous Flora," has heretofore been called the "Shasta flora," but since it does not occur throughout the whole of the Shasta series it has seemed best to abandon its use. It may be desirable at some time in the future to give separate names to the portions of the Shasta series containing the Cretaceous and Jurassic floras respectively.

† Geol. Soc. Am., Bull., vol. xix, p. 373, 1908.

At the summit there are found the invertebrates *Aucella Piochi* and *A. crassicollis*, but between the summit and the plant bed, 1,200 feet below, only faint indications of plants have been noted, though according to Mr. Diller "The plant beds at the so-called Todd locality conformably underlie by a few feet only a conglomerate containing indefinite vegetable fragments as well as good specimens of *Aucella Piochii*." From the presence of shells and plants and the lithologic similarity of the intervening beds to those of the Myrtle, the whole is referred to this formation.

The only Jurassic plant in any way determinable that was found in the area and strata usually containing a Lower Cretaceous flora, occurred about 3 miles northeast of Riddles. This was a minute fragment, which was very questionably identified as *Teniopteris oregonensis*, and was found in association with *Aucella Piochii*. If this identification had been positive, or even reasonably certain, it would be the only known instance of the two floras overlapping, but it is altogether too fragmentary to be taken as conclusively affording such evidence.

3. Nichols Station, Douglas County, Oregon.

This is a small area, mainly on Cow Creek, about half a mile north of Nichols Station, and is entirely surrounded by rocks of Eocene age. The beds, only about 200 feet in thickness, are composed of "fine, dark, shaly sandstone or sandy shale." Their relations to the underlying beds cannot be observed, and their reference to the Myrtle was based largely on a single specimen of *Aucella Piochii*, which was in a loose piece of matrix, not certainly found in the plant beds. As a locality for the Jurassic flora, however, it is of the greatest importance, no less than 45 forms having been found here. [See table on pp. 43-45.]

4. Elk River, Curry County, Oregon.

This area, which lies about 40 miles directly southwest of the areas in Douglas County, is of limited extent, ranging along Elk River from near the mouth of Blackberry Creek to the forks of the river and up the North fork for a distance of about a mile and a half; on the South fork the plant beds extend for only 200 yards. The section is about 1000 feet in thickness and is made up of sandy shale, much veined with calcite, "frequent layers of calcareous material, beds of sandstone, and fine conglomerate."

According to Mr. Diller,* "These plant beds are underlain on the South fork by a mass of conglomerate containing in its

* Op. cit., p. 376.

lower part many large pebbles of the greenstone like that on which the conglomerate rests at the base of the 'Myrtle.' No plants were found in the basal conglomerate, though it contained many examples of *Aucella crassicollis*." On this evidence the entire section was regarded as referable to the Myrtle formation.

Since the above quotation was published, in fact during the past summer (1909), Mr. Diller has visited and re-examined the Elk River region of the Port Orford quadrangle, and made the following important observations which he has kindly permitted me to make use of. The plant beds—that is, the beds containing the "Jurassic flora of Oregon"—he now finds to be over 1,200 feet in thickness; they rest conformably on a conglomerate which he regards as the basal member of the Myrtle (Knoxville). This conglomerate contains "multitudes" of *Aucella crassicollis* in the upper portion, while *Aucella Piochii* occurs, though somewhat rare, near the bottom. This conglomerate rests unconformably on a mass of greenstone, which has supplied the pebbles in its basal portion. This greenstone mass, in turn, has cut the underlying crushed and quartz-veined slates and sandstones of the Dothan? which latter contains locally, as identified by Doctor Stanton, *Aucella Piochii* and *Aucella Erringtoni* in association. This distribution of the several species of *Aucella* in this section is very significant, and will be referred to on a later page.

The Elk River area has furnished two considerable collections of fossil plants which together aggregate 20 species [see table on pp. 43–45]. As this entire flora, with the exception of the unnamed specie of *Hausmannia*, is identical with that found in Douglas County, it may be considered as settled that the two areas are of the same age.

This is also the first of the areas thus far considered in which an identifiable invertebrate fauna is found in direct association with the plants. The following list of names is given by Doctor Stanton:*

Spondylus? sp.
Aucella crassicollis Keyserling
Inoceramus ovatus Stanton
Turbo morganensis Stanton
Olcostephanus mutabilis Stanton
Perisphinctes? sp.
Hoplites Hyatti Stanton
Belemnites tehamensis Stanton
Belemnites impressus Gabb
Pinna.

*In Diller, Geol. Soc. Am., Bull., vol. xix, p. 378, 1908.

Doctor Stanton makes the following comment on this fauna: "The collection consists of a number of small lots containing very few specimens, the most abundant and persistent being *Aucella crassicollis* Keyserling, which past experience shows to be characteristic of the upper part of the Knoxville formation and is believed to be confined to the Lower Cretaceous. In several of the lots there are a few ammonites and other fossils that are also Knoxville forms."

The significance of this association of flora and fauna will be considered later.

5. Big Bar, Trinity County, California.

This area, which covers less than two square miles, is on the Trinity River, about twenty miles west of Weaverville, California, and is not less than 150 miles from the areas already considered in Oregon. The entire section of Jurassic rocks in this vicinity does not exceed 200 feet in thickness, and lies on the sharply upturned edges of older, probably Paleozoic strata, and is itself inclined from 20 to 45°. It is composed of soft "gray shales and sandstones, with a small proportion of fine conglomerate," and apparently belongs to the lower part of the Knoxville.

Fossil plants are abundant in this locality, and are scattered irregularly throughout the section, though most numerous in the lower portion. They embrace 20 well-marked species [see table on pp. 43-45] and as stated in the original report, they "prove beyond question that the beds containing them are similar in age to the Jurassic of Oregon, since all but three of the forms (*Onychiopsis* [fruit], *Hausmannia*, and *Pagiophyllum falcatum*) are common to the two areas."

In the same bed with the plants a few shells have been found. Only one of these has been positively determined as *Aucella crassicollis*, the others being unidentified forms of *Pecten*, *Mytilus*, *Cyprina*, and *Unio*, the latter proving that there were alternations of fresh-water and salt-water conditions. These fossils, says Doctor Stanton, "are certainly upper Knoxville and hence Lower Cretaceous, as shown by the presence of typical specimens of *Aucella crassicollis*."

6. Rattlesnake Creek, Trinity County, California.

Twenty-five miles south of Big Bar there is another small area of Jurassic plant-bearing beds lying in the drainage of Rattlesnake Creek, 7½ miles southwest of Peanut, Trinity County, California. As at Big Bar, the plant beds rest on the upturned edges of older rocks.

Only three species of plants have been found at this locality: *Cyclopteryx oregonensis* Font., *Tæniopteris vittata* Brongn.,

and *Sequoia Reichenbachii* (Gein.) Heer. The latter species is a form of such wide vertical range that it is of little value in fixing the age of beds in which it may occur, hence its inferential use to prove the beds on Rattlesnake Creek to be of extreme upper Knoxville or lower Horsetown age, where this species has also been found, is not warranted.

Many shells are stated to be present in the same strata with the plants, concerning which Doctor Stanton reports as follows: "Among the fossil plants are two small shells which appear to be young specimens of *Unio*, though they may belong to some marine genus instead."

7. Oroville, Butte County, California.

At this locality Jurassic rocks form an area about 2 miles in length and $2/5$ of a mile in width, on the southern slope of Monte de Oro, about 3 miles northeast of Oroville, Butte County, California. These rocks, to which the local name of the Monte de Oro formation has been given, are composed of "slates, sandstones, and conglomerates in small layers, irregularly interbedded"; they are much disturbed and the true thickness cannot be made out, though thought to be somewhere between 450 and 900 feet.

This area has afforded a rich flora, and was the first to be described of any considered in this paper; it contains 27 species [see table on pp. 43-45]. They are typically Jurassic, and as nearly half were subsequently found to be common to the Douglas County region they are of much importance in settling the Jurassic age of the plant beds in the latter area. Unfortunately the invertebrate collections are not large from the plant beds at Oroville, and comprise new or undeterminable species of the genera *Ostrea*, *Pecten*, *Aucella*?, *Modiola*, *Trigonia*, *Cardium*? and *Belemnites*. Regarding the age as indicated by the *Aucella*? Doctor Stanton says: "If it is really an *Aucella* the age is either Mariposa or Knoxville, more probably the former. The general character of the other forms is suggestive of the older Jurassic faunas of the Taylorsville region, but it must be admitted that there is no definite evidence of this."

STRATIGRAPHIC RELATIONS OF THE BEDS CONTAINING THE LOWER CRETACEOUS FLORA OF OREGON AND CALIFORNIA.

1. Near Riddles, Douglas County, Oregon.

In the vicinity of Riddles, Oregon, and including a small area on Iron Mountain Creek, there is a mass of rocks that has been pretty definitely connected with the upper portion of the Myrtle formation, since it is directly on the strike with that

of the type locality for the Myrtle on Myrtle Creek in the Roseburg quadrangle. These beds contain a small but very important flora of 8 species, as follows:

- Sagenopteris Mantelli*? Schenk
- Sagenopteris oregonensis* Font.
- Sagenopteris nervosa* Font.
- Angiopteridium strictinerve latifolium* Font.
- Dioonites Buchianus abietinus* Ward.
- Nageiopsis latifolia* Font.
- Populus*? *Ricei* Font.
- Sapindopsis oregonensis* Font.

This flora is identified without hesitation as being of Lower Cretaceous age, or Neocomian. The presence of the species of dicotyledons shows conclusively that it is younger than the "Jurassic flora of Oregon," a fact also proved by the stratigraphic relations and invertebrate fauna. The latter, although stated to be abundant, is not listed by Mr. Diller, though held to be characteristic and proving the correlation between these beds and those containing a similar fauna on the western side of the Sacramento Valley.

The stratigraphic relations between the beds near Riddles which contain the Lower Cretaceous flora, and those to the northwest containing the Jurassic flora, is well set forth by Mr. Diller* in the following statement: "A line of deformation runs northeast and southwest through the region of Nickel Mountain and Dodson Butte. It follows a prominent ridge and appears to mark approximately the limit between the two floras of 'Myrtle formation.' Southeast of it lies the Riddles region and Iron Mountain Creek, where the "Myrtle formation" contains the 'Shasta flora,' while to the northwest of it lie the larger irregular areas of the 'Myrtle,' containing locally on Thompson Creek and Elk River the 'Jurassic flora of Oregon.' At one point the line of deformation is overlapped by the Jurassic flora, where it reaches Cow Creek at Nichols Station. In general, on account of the overlapping 'Myrtle formation,' it may be claimed that the 'Myrtle' containing the Jurassic flora lying northwest of that containing the Shasta flora must be older. So it seems also from the entire absence of any Horsetown fauna on the northwest side of the axis in the same series near the Jurassic flora."

From this exposition it appears very clear that the Myrtle formation may be divisible, at least paleontologically, into two parts, the upper of which is characterized by the presence of a Lower Cretaceous flora and fauna, while the lower is equally marked by the presence of a Jurassic flora. The two floras

* Op. cit., p. 397.

have never been found commingled, but the fauna is occasionally, as at Elk River, also found interbedded with, as well as below, the Jurassic flora, showing that it has a greater vertical range than has usually been accorded to it.

2. Western Side of the Sacramento Valley in Shasta and Tehama Counties, California.

This is much the largest and most important of the areas which have afforded the Lower Cretaceous flora. It is found at many localities on the North fork of Cottonwood Creek near the town of Ono, Shasta County, and along the Cold fork and South fork of Cottonwood Creek, as well as near the Post Office of Lowrey and as far south as Paskenta, all in Tehama County. The field relations of this region have been so fully set forth by Professor Ward* and Mr. Diller that it is unnecessary again to go over the matter.

This area is also notable as that which has supplied the major portion of the Knoxville fauna, and since small portions of this fauna were found in association with the Jurassic flora at Elk River, Big Bar, etc., it was assumed by some that the flora of the western side of the Sacramento Valley would present the same associations—that is, prove to be a Jurassic flora—but it very distinctly is not. By combining the floras collected by Professor Ward and studied by Professor Fontaine, with those collected by James Storrs for Mr. Diller and reported on by the writer, we have the following aggregate list of 59 forms, only a single species of which is common to the Jurassic flora. It is distinctly a Lower Cretaceous (Neocomian) flora and finds its closest affinity with the Kootenai of the interior region, the Trinity of Texas, and the lower Potomac of the Atlantic Coastal Plain. A further analysis and comparison will be made in later pages.

List of Lower Cretaceous Flora of the Western Side of the Sacramento Valley.

- Dicksonia pachyphylla* Font.
- Thyrsopteris rarinervis* Font.
- Cladophlebis parva* Font.
- “ *Browniana* (Dunk.) Sew.
- “ *falcata* Font.
- “ *heterophylla* Font.
- “ *Ungerii* (Dunk.) Ward.
- “ *alata* ? Font.
- Matonidium Althausii* (Dunk.) Ward.
- Gleichenia Nordenskiöldi* Heer.
- “ ? *Gilbert-Thompsoni* Font.

* U. S. Geol. Surv. Mon. 48, p. 211 et seq., 1905.

- Sagenopteris Mantelli* (Dunk.) Sew.
 " *oregonensis* (Font.) Font.
 " *elliptica* Font.
 " *nervosa* Font.
 " ? sp. Font.
Tæniopteris sp. Kn.
Hausmannia ? *californica* Font.
Angiopteridium canmorensense Dawson ?
 " *strictinerve* Font.
 " *strictinerve latifolium* Font.
Oleandra graminæfolia Kn.
Ctenopteris integrifolia Kn.
Ctenis sp. Kn.
Equisetum texense Font.
Dioonites Dunkerianus (Göpp.) Miq.
 " *Buchianus* (Ett.) Born.
 " " *abietinus* Ward.
 " " *rarinervis* Font. ?
Nilsonia Stantonii Ward.
 " *Shaumbergensis* (Dunk.) Nathorst.
 " *californica* Font.
 " *sambucensis* Ward.
 " sp. Kn.
Pterophyllum lowryanum Ward.
Ctenophyllum ? *latifolium* Font. ?
Zamites arcticus Göpp.
 " *tenuinervis* Font.
Cycadeospermum alifornicum Font.
 " sp. Kn.
Cephalotaxopsis ramosa Font. ?
 " *rhytidodes* Ward.
Nageiopsis longifolia Font.
 " *latifolia* Font.
Abietites ellipticus Font.
 " *macrocarpus* Font.
 " sp.
Pinus shastensis Font.
Sequoia Reichenbachii (Gein.) Heer.
 " *ambigua* Heer.
Sphenolepidium Sternbergianum (Dunk.) Heer.
Saliciphyllum pachyphyllum Font.
 " *californicum* Font.
Populus ? *Ricei* Font.
Proteaphyllum californicum Font.
Menispermities californicus Font.
Sapindopsis oregonensis Font.
Acaciaphyllum ellipticum Font.
 " *pachyphyllum* Font.

3. Redding Creek, Trinity County, California.

The final area of beds holding a Lower Cretaceous flora to be considered is the small one on Redding Creek, near Douglas City, Trinity County, California. It is said that the beds at this locality lap over the crest of the Coast Range from the Sacramento Valley, and are of the same age as the beds in the latter area. The flora is a small one, comprising only the following species :

Sagenopteris oregonensis Font.

Sagenopteris elliptica ? Font.

Gleichenia ? *Gilbert-Thompsoni* Font.

Cladophlebis heterophylla Font.

Sequoia Reichenbachii (Gein.) Heer.

These specimens, with the exception of *Cladophlebis heterophylla*, which is known from the Kootenai and lower Potomac, are all reported by Fontaine and the writer from the Lower Cretaceous flora of the localities along the western side of the Sacramento Valley, in direct connection with these beds, as stated above.

The fauna associated with the plants embraces *Pecten operculiformis*, *Trigonia leana*, *Cardium*?, *Corbula*, and *Pleuromya papyracea*, and is regarded by Doctor Stanton as belonging to the lower Horsetown.

TABLE SHOWING LOCAL DISTRIBUTION OF THE JURASSIC FLORA.

As a preliminary to the proper consideration of the Jurassic flora in all its aspects, we may first present a table which gives a complete list of forms known, together with their distribution among the several localities in Oregon and California. The number, or numbers, opposite each species, refer to the localities as follows :

- 1 = Thompson Creek, Oregon.
- 2 = Buck Peak, Oregon.
- 3 = Nichols Station, Oregon.
- 4 = Elk River, Oregon.
- 5 = Big Bar, California.
- 6 = Rattlesnake Creek, California.
- 7 = Oroville, California.

Marchantites erectus (Bean) Sew., 1.

Dicksonia oregonensis Font., 1, 2, 4, 5.

Coniopteris hymenophylloides (Brongn.) Sew., 3, 7.

Thyrsopteris Murrayana (Brongn.) Heer, 1, 3, 4.

Polypodium oregonense Font., 1, 2, 3, 4.

Cladophlebis vaccensis Ward, 1, 2, 3, 4, 5, 7.

“ *haiburnensis* (L. & H.) Br. ? 1.

“ *acutiloba* (Heer) Font., 1, 3.

- Cladophlebis denticulata* Font., 5?
 “ *pecopteroides* Font., 2, 4?
 “ *sphenopteroides* Font., 5.
 “ *spectabilis* (Heer) Font., 7.
 “ *argutula* (Heer) Font., 7.
 “ *densifolia* Font., 7.
 “ *indica* (O. & M.) Font., 7.
 “ sp., Kn., 5.
Scleropteris oregonensis Font., 3, 5?
Ruffordia Göpperti (Dunk.) Sew., 1.
Adiantites Nympharum Heer? 1, 3.
 “ *orovillensis* Font., 7.
Tæniopteris orovillensis Font., 1, 2, 3, 5, 7.
 “ *major* L.? & H., 1, 2, 3.
 “ *vittata* Brongn., 1, 2, 3, 5, 6.
 “ ? *oregonensis* Font., 1, 4.
 “ sp., 5.
Macrotæniopteris californica Font., 1, 7.
 “ *nervosa* Font., 7.
Angiopteridium californicum Font., 7.
Sagenopteris Göppertiana Zigno, 1, 2, 4, 7.
 “ *paucifolia* (Phil.) Ward, 1, 2, 3, 4, 5.
 “ *grandifolia* Font., 1, 5.
Danæopsis Storrsii Font., 1.
Didymosorus? bindrabundensis acutifolius Font., 7.
Hausmannia sp., 4, 5.
Onychiopsis psilotoides (Stokes & Webb) Ward? 5.
Equisetum? sp., Font., 1, 3.
Ptilozamites Leckenbyi (Bean) Nath., 3.
Nilsonia orientalis Heer, 1, 2.
 “ “ *minor* Font., 1, 2, 3, 4, 5.
 “ *parvula* (Heer) Font., 1, 2, 3, 4.
 “ *nipponensis* Yokoyama, 1.
 “ *compta* (Phil.) Göpp., 1, 3.
 “ *pterophylloides* Nath., 1, 3.
 “ sp., Kn., 4.
Pterophyllum Nathorsti Schenk, 1, 2, 3.
 “ *contiguum* Schenk, 1, 2, 3.
 “ *æquale* (Brongn.) Nath., 1, 2, 3.
 “ *rajmahalense* Morris, 1, 2, 3.
 “ *minus* Brongn., 1.
Ctenis grandifolia Font., 1, 2, 3, 7.
 “ *auriculata* Font., 1?, 7.
 “ *orovillensis* Font., 1, 7.
 “ *sulcicaulis* (Phil.) Ward, 1, 2, 3, 4?
Ctenophyllum angustifolium Font., 1, 4, 7.
 “ *pachynerve* Font., 3.
 “ *Wardii* Font., 1, 2, 3, 7.
 “ ? n. sp.? Font., 4.
 “ *densifolium* Font., 7.
 “ *grandifolium Storrsii* Font., 7.

- Podozamites pulchellus* Heer, 1, 2, 3.
 " *pachyphyllus* Font., 2, 3.
 " *lanceolatus* L. & H., 1, 2, 3, 7.
 " " *latifolius* (Brongn.) Heer, 1, 4, 7.
 " " *minor* (Sch.) Heer, 1, 4, 5.
 " sp., Kn., 4.
 " ? *pachynervis* Font., 1.
Otozamites oregonensis Font., 4.
Encephalartos? *oregonensis* Font., 2.
Cycadeospermum oregonense Font., 1.
 " *ovatum* Font., 1.
Williamsonia oregonensis Font., 1.
 " ? sp., Font., 1.
 " ? sp., Font., 3.
Ginkgo digitata (Brongn.) Heer, 1, 3.
 " *Huttoni* (Sternb.) Heer, 1, 3.
 " " *magnifolia* Font., 1, 2, 3.
 " *lepida* Heer, 1, 2, 3.
 " *siberica* Heer, 1, 3.
 " sp., Font., 1, 3.
Baiera multifida Font., 7.
Phœnicopsis? sp., Font., 1.
Tuxites zamioides (Leck.) Sew., 1, 2, 3, 4, 5.
Brachyphyllum mamillare Brongn., 1.
Pagiophyllum Williamsonis (Brongn.) Font., 7.
 " *falcatum* Font., 5?
Araucarites sp., Font., 1.
Pinus Nordenskiöldi Heer, 1, 3, 7.
Sequoia Reichenbachii (Gein.) Heer, 6.
Cyclopitys oregonensis Font., 1, 6.
Sphenolepidium oregonense Font., 1, 2, 3, 5.
Samaropsis? *oregonensis* Font., 1.
Leptostrobus? sp., Font., 7.
Yuccites hettangensis Sap., 1, 5?
 Undetermined leaf No. 1, 1.
 " " " 2, 1.
Carpolithus Storrsii Font., 7,
 " *olallensis* Ward, 1.
 " *Bucklandii* Will., 1.
 " *oregonensis* Font., 1, 2.
 " *elongatus* Font., 1.
 " *douglasensis* Font., 3.

DISCUSSION OF THE DISTRIBUTION AND AFFINITY OF THE JURASSIC FLORA.

Aside from furnishing a complete list of the forms thus far known from the Jurassic of Oregon and California, the above table brings out graphically a number of interesting points, perhaps the most important of which is the close interrelation

of the floras of the several areas. Thus, of the 27 species composing the Oroville flora, 12 species occur also in the Douglas County areas. Of the 66 forms found on Thompson Creek, 32 are common to the localities near Nichols Station, and of the 20 forms occurring at Elk River, in Curry County, all but one are common to Douglas County. The close relation between the Oregon areas and that at Big Bar, California, is shown by the fact that all but 3 of its 19 forms are common to the former, and of the 3 species reported from Rattlesnake Creek, 2 are common to the Oregon localities and one to Big Bar. This proves beyond all reasonable doubt that the plant beds of the several localities are identical in age. Whatever is decided regarding any one of them must apply with equal force to all.

We may now proceed to an analysis of the flora to ascertain its bearing on the age of the strata. Of the 100 forms composing the flora 15 are not specifically named and 47 are found in outside areas, mainly beyond the limits of North America, thus leaving 38 species, or considerably less than fifty per cent., as endemic. Of these forms that are peculiar, Professor Fontaine* has well said that "none are incompatible with the conclusion that the age of the strata is Jurassic. On the contrary, so far as they throw any light on the question of age, they indicate that it is Jurassic."†

The value of species new to science and those whose determination is questioned, in attempting to fix the age of the beds containing them lies in their affinities, or close relationship, with species whose position is known. It may be worth while in the present connection to review a number of the peculiar species of this flora to ascertain their relationships. *Cladophlebis vaccensis* is very close to, and indeed was at first identified with, *Asplenium whitbiense tenue* Heer, from the Jurassic of Siberia. *Cladophlebis pecopteroides* is thought by Professor Fontaine to be the Oregon representative of *Pecopteris obtusifolia*, a species of the Yorkshire beds. *Scleropteris oregonensis* is close to *S. Pomelii* Zigno of the Italian Oölite. *Teniopteris?* *oregonensis* may be a small, narrow leaf of *T. vittata*, though it has some resemblance to *Cycadites sibericus* Heer, of the Jurassic of Siberia, which is a *Teniopteris* rather than a

* U. S. Geol. Surv., Mon. 48, p. 141.

† Mr. Diller has given a portion of this quotation ["so far as they throw any light on the question of age, they indicate that it is Jurassic"] as a full expression of Professor Fontaine's opinion regarding the bearing of the Oregon plants on the question of age. As shown above, this quotation applies only to the new and not specifically named species, while Fontaine's opinions regarding the significance of the positively determined species occur on the two or three succeeding pages of his paper [U. S. Geol. Surv., Mon. 48, pp. 141-145].

Cycadites. *Danceopsis Storrsii* shows affinity with *D. marantacea* Heer, and *D. Rumpfii* Schimper, two Triassic species, though it is smaller. *Ctenophyllum angustifolium*, as Fontaine points out, is "plainly one of the narrow-leaved Ctenophylla of the type of *Ctenophyllum Braunianum* (Göpp.) Schimper." *Podozamites pachyphyllum* resembles a number of species, but is especially like *Pterophyllum? cteniforme* Nathorst, from the Rhaetic of Sweden. *Williamsonia oregonensis* very much resembles *W. gigas* (Will.) Carruthers, a well-known species of the Jurassic of France and elsewhere. *Tæniopteris orovillensis*, the most common fossil plant at Oroville, is very near the plant figured and described by Saporta as *T. tenuinervis* Braunn from the Infralias of France. *Macrotaeniopteris californica*, which is also a common form at Oroville, is near *T. lata* Oldh. & Morr., of the Rajmahal flora of India. *Angiopteridium californicum* is quite similar to *A. McClellandi* (Oldh. & Morr.) Schimper, from the same locality and horizon as the last.

This comparison could be much further elaborated, but it is perhaps unnecessary.

A COMPARISON OF THE JURASSIC FLORAS OF CALIFORNIA AND OREGON HERE CONSIDERED WITH KNOWN JURASSIC FLORAS OF OTHER PARTS OF THE WORLD.

The Jurassic flora is one of the most widely known and uniformly distributed of any known fossil flora. Reaching its northernmost limit on King Karl's Land, 82° N., and its southernmost extension on Louis Philippe Land, 63° S., it is found entirely round the world in almost every continent and country—North America, Europe, Asia, Australia. Throughout this vast area it is to all intents and purposes practically the same flora. For example, many of the forms discovered on Louis Philippe Land are identical, or closely related, to those of the Oölite of Yorkshire, England, while many forms, identical or closely related, are common between the areas in England, Sweden, France, Italy, Germany, Siberia, China, Japan, India, or North America.

The types of the Jurassic flora are for the most part well marked, and even when only fairly well preserved are capable of very certain identification. When to this is added the fact that in most areas where this flora has been found its position is confirmed by contributory stratigraphic and paleontologic data, the fixation of a similar flora found in a new area is made easy and certain.

It is proposed to compare the flora here under consideration with that of several of the more important of the known Jurassic floras of the world, beginning with that of Eastern

Siberia. At first thought it may seem a far call from California and Oregon to Siberia, but when it is pointed out that there are a number of connecting points at which the Jurassic has been found in western British Columbia, southern and western Alaska, and thence out on the Alaskan peninsula, it is seen that we have here indication of a probable land connection between the continents in Jurassic time.

In 1876 Heer* published his first paper on this flora which included material from Kajamündung and Ust-Bali, Siberia, and the upper Amur River, and Bureja in the Amur. This was supplemented† in 1878 and 1880 by the study of further material from the original localities as well as from the Lena delta, etc. The number of species finally aggregated about 100, many of which have since been identified in widely different parts of the world, the greatest number (16 species) being common to the beds of Yorkshire, England. The age of the Siberian deposits was fixed by Heer as that of the middle Brown Jura (Dogger), which is about the equivalent of the lower Oölite of Yorkshire.

Following is the list of species common to California and Oregon and eastern Siberia:

<i>Cladophlebis argutula</i>	<i>Podozamites lanceolatus minor</i>
<i>Cladophlebis acutiloba</i>	<i>Podozamites lanceolatus latifolius</i>
<i>Cladophlebis spectabilis</i>	<i>Ginkgo digitata</i>
<i>Thyrsopteris Murrayana</i>	<i>Ginkgo Huttoni</i>
<i>Thyrsopteris Maakiana</i>	<i>Ginkgo lepida</i>
<i>Nilsonia orientalis</i>	<i>Ginkgo siberica</i>
<i>Nilsonia parvula</i>	Seeds of <i>Ginkgo</i>
<i>Pterophyllum rajmahalense</i>	<i>Pinus Nordenskiöldi</i>
<i>Podozamites pulchellus</i>	<i>Brachyphyllum mamillare.</i>
<i>Podozamites lanceolatus</i>	

As Professor Fontaine has pointed out, the strata of Oregon and California rival those of eastern Siberia in the development of Ginkgos, and as he says, it is a noteworthy fact that nearly all of the more important forms described by Heer from those beds have similar forms in the Oregon strata. Certain of the forms, notably that known as *Ginkgo digitata*, have a distribution into somewhat later beds, but in these later horizons, such for example as the Kootenai formation, they are smaller and not present in such numbers. In fact the Ginkgos in the Lower Oölite time were immensely developed in the Amur region of Siberia and in the northwestern portion of the

* Beiträge z. Jura-Flora Ostsibiriens u. d. Amurlandes. Mém. Acad. Imp. d. Sci. St. Petersb. (Fl. Foss. Arct., vol. iv, Abt. 2), vol. xxii, pp. 1-122, pls. i-xxxii, 1876.

† Op. cit., vol. xxiv, 1878 (Fl. Foss. Arct., vol. v, Abt. 1), pp. 1-26, pls. i-vii. Op. cit., vol. xxii, 1880 (Fl. Foss. Arct., vol. vi, Abt. 1), pp. 1-34, pls. i-ix.

United States, a profusion of identical forms such as to suggest very forcibly the existence of a former land connection.

At the present point it will be of interest to consider the occurrence of Jurassic plants at various localities in Alaska, the first and in many respects most important being the areas along the west shore of Cook Inlet. In this area Stanton and Martin* have established the Enochkin formation, the upper part of which they regard as the equivalent of the Callovian of European standards. Following German usage, this is considered by these authors as belonging to the upper part of the Middle Jurassic, though according to the prevailing custom of English geologists it belongs to the upper part of the Lower Oölite. The upper two-thirds of the Enochkin formation, which has a total thickness of from 1,500 to 2,500 feet, is especially characterized by the presence of numerous species of *Cadoceras*, several other genera of ammonites, belemnites, etc. Associated with these shells, often being on the same pieces of matrix, were the following plants:

Cladophlebis denticulata

Ctenis grandifolia

Hausmannia sp.

Dictyophyllum cf. *D. obtusilobum*.

The lower third of the Enochkin formation contains a fauna very different from that of the upper portion. It is characterized by species of *Stephæroceras*, *Sphæroceras*, *Phylloceras*, *Lytoceras*, etc., the genus *Cadoceras* being absent, and the most common forms being the several species of *Inoceramus* described by Eichwald from this region. It is interesting to note that this fauna was originally referred largely, if not wholly, to the Neocomian by Eichwald, and also that several of its species were found to be the same as those from Queen Charlotte Islands, once referred by Whiteaves to the Cretaceous. Associated with the ammonites were the following plants:

Sagenopteris Göppertiana

Pterophyllum rajmahalense

Macroteniopteris californica.

It is of importance to note that every one of the five named and positively identified species from the Enochkin formation occurs in the Oroville (Monte de Oro) flora. Several important inferences may be drawn from the intimate relation between the floras of these two areas. Thus, the Mariposa formation, with which the Monte de Oro formation has been identified, is regarded by Stanton as referable to the late Jurassic, but if a

* Geol. Soc. Am., Bull., vol. xvi, p. 397, et seq., 1905.

considerable element of the Oroville flora occurs in Alaska in association with an invertebrate fauna acknowledged to be of Middle Jurassic age, it would seem to follow that the Mariposa is also of similar age. The interpretation of the bearing of the invertebrates on this question must naturally be left to the invertebrate paleontologists, but this much can be said: The plant evidence, as above stated, is distinctly in favor of regarding the Mariposa as much older than "late Jurassic."

Other localities in Alaska are as follows: From Herendeen Bay, in association with shells of *Aucella crassicollis*, we have *Pterophyllum alaskense* Font., a form very closely related to *P. rajmahalense*, in fact hardly to be separated from it. The latter species is one of the most abundant and important of those found in the Oregon locality. Near Nikolai in the Copper River region occurs *Sagenopteris alaskense* Font., which is near *S. Göppertiana* of the lower Oölite of Italy, and which is found also at Thompson Creek, Elk River and Oroville. From the vicinity of Cape Lisburne quite large collections have been obtained. These comprise 14 species which were considered by Fontaine to be of Jurasso-Cretaceous age, but a study of large additional collections since secured, together with a review of much of the original material, has convinced the writer that they are of the same age as the other Alaskan and Pacific Coast plant beds. About half of the Cape Lisburne species are identical with those of Oregon or California. The final locality is between Icy Cape and Wainwright Inlet, some 180 miles northeast of Cape Lisburne. This place has afforded *Podozamites* sp. and *Baiera gracilis*, the latter a species characteristic of the Yorkshire beds.

On account of the larger number of common species, the next area to be compared, although not logically next from a geographical point of view, is Yorkshire, England, which has in common with the California-Oregon region the following:

<i>Marchantites erectus</i>	<i>Pterophyllum minus</i>
<i>Cladophlebis denticulata</i>	<i>Nilsonia compta</i>
<i>Cladophlebis haiburnensis</i>	<i>Podozamites lanceolatus</i>
<i>Coniopteris hymenophylloides?</i>	<i>Ctenis sulcicaulis</i>
<i>Thyrsopteris Murrayana</i>	<i>Cycadeospermum Bucklandii?</i>
<i>Ruffordia Göpperti</i>	<i>Ginkgo digitata</i>
<i>Tæniopteris major</i>	<i>Taxites zamioides</i>
<i>Tæniopteris vittata</i>	<i>Brachyphyllum mamillare</i>
<i>Sagenopteris paucifolia</i>	<i>Pagiophyllum Williamsonis.</i>
<i>Ptilozamites Leckenbyi</i>	

The flora of the Yorkshire beds has been made the subject of an exhaustive study by Seward,* published in 1900. The

* Cat. Mesoz. Pl. Brit. Mus., Jurassic Fl., I., Yorkshire Coast.

Jurassic forms a narrow band across England from Yorkshire to Dorsetshire, the plant-bearing beds being especially well represented in the vicinity of East Yorkshire. The area has been a favorite collecting ground for English students for nearly or quite a hundred years, with the result of bringing together a large amount of material. Professor Seward has re-studied such of the old type material as is now available, together with that of more recent date, and as a result has been able to give a very full and satisfactory account of this flora. The age of the Yorkshire plant beds has been very definitely fixed as Lower Oölite.

Certain of the species enumerated in the above list are very characteristic of the Yorkshire flora, such for instance as *Cladophlebis denticulata*, *Thyrsopteris Murrayana*, *Ptilozamites Leckenbyi*, *Nilsonia compta*, *Otenis sulcicaulis*, *Brachyphyllum mamillare*, *Pagiophyllum Williamsonis*, etc. They are, for the most part, forms not likely to be misidentified, and therefore of especial importance in the present connection.

Jurassic plants are known from a number of localities in France, the more important being Mamers, D'Ethrocley, and Châteauroux, in the departments of Sarthe, Côte d'Or, and Indre, respectively. A considerable number of species are common to these French localities and the English beds just considered, while there are in common with the Pacific Coast at least the following:

Tæniopteris vittata
Brachyphyllum mamillare
Ginkgo digitata.

A single species (*Sagenopteris Göppertiana*) has been reported by Zigno from the Lower Oölite of Italy.

It is of interest to note that there are two species—*Pterophyllum contiguum* and *P. Nathorsti*—found in the Oregon beds that have previously been reported only from the Kweichow beds of China. According to Schenk this horizon cannot be older than Lower Jurassic, and, as Fontaine has stated, since the beds contain *Podozamites lanceolatus* and *Nilsonia compta*, it is most likely that the age is Lower Oölite, certainly not younger. *Pterophyllum æquale* has been noted by Schenk in the Tumulu coal fields of China, in beds of Lower Oölitic age.

In the Kaga strata of Japan, which Yokayama refers to the Lower Oölite, we have *Nilsonia nipponensis*, a species represented by several fairly well preserved examples in the Oregon beds.

There are a few species in the Pacific Coast flora that have heretofore been found only in older beds. Thus, *Pterophyllum rajmahalense* was first found in the Rajmahal series of India, which is held to be of Liassic age, but as this does not differ apparently from Heer's *Pterophyllum sensinovianum* from the Jurassic of Siberia, if Heer's conclusion as to the age of the strata containing it is correct, it appears to have persisted into the Lower Oölite. It is one of the most important and abundant forms at a number of the Oregon localities, occurring literally in hundreds of specimens.

Another species regarded by Fontaine as possibly common to the Rajmahal series is *Cladophlebis indica*, though it is represented by a single example and thus is not of great importance, and the variety of *Didymosourus bindrabundensis* is but a slight variation from the species as known from these beds; it is also represented by a small fragment only.

The following species are believed to be common to the Rhaetic of Sweden: *Nilsonia pterophylloides* and *Pterophyllum æquale*, while portions of a plant have been identified as *Baiera multifida*? from the older Mesozoic (Rhaetic) of Virginia.

From this it appears that a few of the forms had their origin in older beds and persisted into this stage of the Jurassic, but none of those above enumerated is known to continue into higher horizons.

Having considered those species evidently older, it will be of interest to enumerate those continuing above the Jurassic. The following species have been found in Wealden, Neocomian, or higher beds:

Onychiopsis psilotoides
Ruffordia Göpperti
Podozamites lanceolatus
Ginkgo siberica or *digitata*
Sequoia Reichenbachii.

The species first mentioned, which was doubtfully identified in the beds at Big Bar, is a common species of the English Wealden, and forms suggestive of it, though they have often been given other names, occur in the lower Potomac of Virginia, the Cenomanian of Niederschöna, etc. *Ruffordia Göpperti* is likewise found in the Wealden of England. *Podozamites lanceolatus*, as Professor Fontaine has pointed out, is "probably a much abused type of leaf. It probably is not a species, but rather a type of leaf found in many species which lived in Jurassic times. The original is from the Lower Oölite and the form is probably more characteristic of that period than any other." Leaves that have been identified as

belonging to this species have been found well up in the Cretaceous. *Ginkgo siberica* (or *digitata*) has already been discussed, while *Sequoia Reichenbachii* has been mentioned as the only species common to the Lower Cretaceous flora of California and Oregon. It ranges through the Cretaceous, principally in the upper part.

As has been so often stated, the mere presence of a species in a list is not all that is required to make it of value in fixing age. The plant must be abundant in a flora and characteristic of it. It may be a survivor from an older flora, or the first appearance of a form destined to become a dominant factor in a later horizon. It is for this reason that so much stress has been laid on relative abundance of species in the several parts of this paper, but to bring it out still more forcibly the following may be enumerated as filling such requirements:

Dicksonia oregonensis (close to *D. gracilis* Heer), *Polypodium oregonense*, *Tæniopteris orovillensis*, *Tæniopteris major*, *Tæniopteris vittata*, *Macrotaeniopteris californica*, *Sagenopteris Göppertiana*, *Sagenopteris paucifolia*, *Nilsonia orientalis*, *Nilsonia parvula*, *Pterophyllum Nathorsti*, *Pterophyllum contiguum*, *Pterophyllum æquale*, *Pterophyllum rajmahalense*, *Podozamites lanceolatus*, *Otenis sulcicaulis*, *Ginkgo digitata*, *Ginkgo Huttoni*, *Ginkgo lepida*, *Ginkgo siberica*, *Taxites zamoides*, *Brachyphyllum mamillare*. Certain of these exist literally in hundreds in the beds.

AGE OF THE "JURASSIC FLORA OF OREGON."

Following is Professor Fontaine's* final opinion regarding the age of the beds containing the Jurassic flora: "There can be no doubt, in the opinion of the present writer, that the Yorkshire Lower Oölites, the strata of eastern Siberia and of the Amour, made known by Heer, and the Oregon beds are of the same age. The only question is, What is that age? The investigations of the English geologists would seem to have settled the question for the Yorkshire formation. . . . So far as my knowledge goes, no one has questioned the correctness of the conclusions of the English geologists regarding the age of the Yorkshire strata. That being established as Lower Oölitic would certainly indicate a similar age for the Siberian beds and also for those of Oregon."

The facts that have been presented in the preceding pages regarding relative abundance and world distribution prove beyond any reasonable question that the above statement is correct, and it is confidently asserted that the "Jurassic flora of Oregon" is a true Jurassic flora. This age determination

* U. S. Geol. Surv., Mon. 48, 1905, p. 144.

has been held by the writer for some years; in fact all original as well as subsequent collections have tended to prove it, as they have also the distinctness of the Jurassic and Cretaceous floras of the region. I have, however, ventured to submit the question to Prof. A. G. Nathorst of Stockholm, who is perhaps the greatest living authority on the Jurassic floras of the world. His comment is as follows: "As to the 'Jurassic flora' of Douglas County, Oregon, I can but think that the American paleobotanists are *right* in regarding it as a true Jurassic flora. For even if some of the specific determinations are incorrect, this has no influence on the question of age. *If*, therefore, the *same* flora is found in California, it is naturally also of Jurassic age. In this matter I do not think it possible that there can be more than one opinion prevailing among paleobotanists."

A COMPARISON OF THE JURASSIC AND LOWER CRETACEOUS FLORAS OF THE OREGON-CALIFORNIA AREAS.

If these two floras comprised a small number of species each, it could be argued that lack of identical forms might be corrected by more extensive collections, but fortunately both floras are relatively large, the Jurassic embracing 100 and the Lower Cretaceous 59 forms. Most of the localities have been extensively—even exhaustively—exploited, and the numbers are sufficiently large to bring out the interrelationship if such existed. An examination of the two lists, however, shows that there is only a single species (*Sequoia Reichenbachii*) common to the two, and as this species is of very wide vertical range, it would seem to be settled conclusively that there is no real relationship between the Jurassic and Lower Cretaceous floras. This conclusion is made more positive and significant by the fact that in certain localities, as near Riddles, they occur practically in the same section. That they may yet be found commingled in the same beds is a contingency that seems highly improbable, though that the Jurassic flora may sometime be found in the lower part of the Knoxville of the Sacramento Valley, below the Lower Cretaceous flora and fauna, is quite possible.

It is not within the scope of the present paper to enter into an exhaustive discussion of the Lower Cretaceous flora of California and Oregon beyond the general statement of its obvious affinities. To some extent this has already been done by Professor Fontaine.*

EVIDENCE OF THE INVERTEBRATES.

As stated in the opening paragraphs of this paper, it is not the intention to enter into a critical analysis of the inverte-

* U. S. Geol. Surv., Mon. 48, pp. 270-273, 1905.

brate faunas, as the writer does not feel competent to do this, but simply to point out certain salient facts regarding their distribution and interpretation. In the first place, to mention briefly the invertebrate faunas associated with the Lower Cretaceous flora of California and Oregon, it may be observed that there is no conflict between the two lines of evidence. Thus, near Riddles, Oregon, as Mr. Diller says: "Both fauna and flora agree with the stratigraphy in correlating this area of the 'Myrtle' with the Shasta on the western side of the Sacramento Valley." In the area on Redding Creek, California, the shells are regarded as being of lower Horsetown age, which agrees with the Shasta age of the plants, while concerning the numerous localities on the western side of the Sacramento Valley, the plants and shells are again in accord with the stratigraphy as regards the position and identity of the beds. That they are of Lower Cretaceous age no one appears to question.

Turning now to the areas which have supplied the Jurassic flora, we find that at Thompson Creek the only invertebrate evidence is a fragment that may not even be a shell. At Buck Peak the nearest plant horizon is 1200 feet below the point at the summit where *Aucella crassicollis* is found, though only a short distance below a conglomerate containing *Aucella Piochii*. The only plant found in the intervening beds—and this a mere fragment—occurs near Riddles, also in association with shells of *Aucella Piochii*. From the area near Nichols Station, one of the most important of the plant localities, a single example of *Aucella Piochii* is reported, but it was not found in place and it is not known that it even came from the plant beds, though possibly it did. In the beds at Rattlesnake Creek, the only invertebrate evidence reported is that of "two small shells which appear to be young specimens of *Unio*, though they may belong to some marine genus instead"; obviously they are not of importance in fixing the age.

There remain for consideration but three localities at which a fauna has been found in direct and positive association with the Jurassic flora. First, that at Oroville, California, where the invertebrates, while not abundant or very well preserved, are regarded as "more probably" belonging to the Mariposa, with a suggestion of the resemblance to the older Jurassic faunas of the Taylorsville region. Here again fauna, flora and stratigraphy are in agreement. It finally resolves that Big Bar, California, and Elk River, Oregon, are the only localities at which flora and fauna are apparently not in accord. The only named invertebrate found at the first mentioned locality is *Aucella crassicollis*. Concerning this and the

unnamed or unidentifiable forms found with it, Doctor Stanton reports as follows: "The fossils from Big Bar, California, area are certainly upper Knoxville, and hence Lower Cretaceous, as shown by the presence of typical specimens of *Aucella crassicollis*. The other invertebrate fossils from the same area are closely associated stratigraphically with the *Aucella*, but as they are either undescribed or unidentifiable species, they do not throw any additional light on the question of the age of the beds."

On combining the faunas of Big Bar and Elk River there are found seven named species, of which the most important and characteristic is regarded as *Aucella crassicollis*, which Doctor Stanton says "past experience shows to be characteristic of the upper part of the Knoxville formation, and is believed to be confined to the Lower Cretaceous."

The new facts regarding the distribution of the several species of *Aucella* in the section at Elk River, which resulted from Mr. Diller's re-examination of the area during the past summer and which has already been briefly alluded to [p. 37], is of much significance in the present connection. From this evidence it appears that not only is the principal horizon for *Aucella crassicollis* in the basal member of the Knoxville and beneath that of the Jurassic plant beds, but *Aucella Piochii*, supposed to characterize the lower portion of the Knoxville—indeed so occurring in the Elk River section—has been found in the underlying slates of probable Dothan age in association with *Aucella Erringtoni*, which is a typical Mariposa species! The wide vertical range here shown for *Aucella crassicollis* and *A. Piochii* would certainly seem to disqualify them as diagnostic or key fossils.

The interpretation that is to be given the Knoxville fauna as a whole may now be considered, and it requires only a brief review of the literature to show that the invertebrate paleontologists are not in agreement among themselves as to what this shall be. Thus, Doctor Stanton* regards the entire fauna of the Knoxville formation as of Neocomian age. After reviewing the differences of opinion regarding the age of certain Russian beds, he continues: "It is evident, then, that even if it were possible to refer the Knoxville to definite horizons of the Russian *Aucella* beds, its age might still be questioned. One important fact that should be borne in mind is that structurally and faunally, so far as known, the Knoxville is a unit. It is true that there is a gradual change in the fauna from the lower to the upper beds, but there is no distinct break that would justify the reference of one portion to the Jurassic and another to the Cretaceous. There are some elements of the

* U. S. Geol. Surv., Bull. 133, p. 30, 1895.

fauna, such as *Belemnites tehamænsis*, *Hoplites Storrssii*, and some of the Turbinidæ, that resemble European Upper Jurassic types. *Aucella Piochii* belongs to the same general type as *A. mosquensis*, which has usually been referred to the Jurassic, and it is somewhat closely related to the Aucellæ of the Mariposa beds; but Professor Pavlow informs me that Aucellæ very similar to *A. mosquensis* occur in the Neocomian of Russia also. These resemblances are not considered of sufficient importance to counterbalance the evidence of the Cretaceous age of the entire series. Some Jurassic elements are naturally to be expected in the Lower Neocomian, and it is well known that in Europe several species of ammonites pass up from the Jurassic to the lowest Cretaceous beds."

On the other hand, Prof. A. P. Pavlow,* the distinguished Russian geologist and paleontologist, in reviewing the Knoxville species of *Aucella*, takes issue with Doctor Stanton as to the age of the beds. He says: "I share perfectly the opinion of Diller and Stanton that the different parts of the Knoxville series contains each its own *Aucella* fauna, which becomes modified gradually. But I cannot share the opinion that all the Knoxville ought to be referred to the Cretaceous system. At least in that which concerns its lower part characterized by *Aucella Gabbi* (*Aucella Piochii* type) I do not find data sufficient to take this side, since the *Aucella* beds speak more in favor of placing these lower beds in the Portlandian, or perhaps in the Aquilonian (though for this last there are only a few indications). The upper part of the series, which is the larger (2000 feet), offers an *Aucella* fauna of the character of the Lower Cretaceous."

If this view be accepted—and it may be added that it corresponds well with the plant evidence—the Knoxville will be divided into two parts, of which only the upper (2000'±) will be Cretaceous, while the remainder (18,000') of the great section will be relegated to the Jurassic. Professor Pavlow was of course unaware of the fact that the two species of *Aucella* (*A. Piochii* and *A. crassicollis*) overlap in range to the extent just shown at Elk River and elsewhere, and the deciding factor in drawing the Jurasso-Cretaceous line may well be the floras.

Another one to write upon the subject is Dr. Emil Haug† of Paris, who, after enumerating a number of Knoxville forms, which he says "have for a long time been parallelized with the Neocomian of Europe," proceeds as follows: "However, the work of Mr. Stanton contains also several *Hoplites*, described as new species, but which are close neighbors of species of the

* Nuov. Mém. Soc. Impér. Nat. Moscow, vol. xvii, p. 83, 1907.

† Bull. Geol. Soc. France (3), vol. xxvi, p. 226, 1898.

horizon of Stramberg, some among them being even very probably identical with these last. There can be no doubt that the lower part of the "Knoxville beds" corresponds to the upper Portlandian of the Mediterranean region."

This view is even more revolutionary than that of Professor Pavlow, since if the genus *Hoplites*, as represented in the Knoxville, is taken as the gauge of Jurassic age, it will carry with it practically the entire Knoxville fauna, which is found in direct association with one or the other of the five species recognized in this genus.

More recently still Prof. James Perrin Smith, in an article on "Salient Events in the Geologic History of California,"* has expressed his conviction, based on invertebrate as well as stratigraphic evidence, that the line between Jurassic and Cretaceous shall be drawn through the Knoxville and not at its base. He says: "After this mountain-making epoch near the close of the Jurassic, the sea again encroached on the uplifted area, and the Knoxville sediments were laid down on the western border of the Coast Range. The lower Knoxville beds contain a fauna closely related to that of the Mariposa, still with Jurassic types of *Aucella*, and with the same poverty of other animals. But the upper Knoxville beds, while still retaining reminiscences of the Boreal Region in *Aucella* and a few other forms, show a preponderance of life characteristic of more favorable conditions. *Aucellas* of more northerly habit mingle with cephalopods that did not belong in the Boreal Region, and on the nearby land cycads abounded. The line between Jurassic and Cretaceous should be drawn, not at the beginning of the Knoxville but between the lower and upper Knoxville beds; the former belonging to the Portland and Aquilonian, while the latter belong to the Neocomian."

Enough has been presented to show that there is more or less difference of opinion regarding the bearing of the invertebrates of the Knoxville on the question of age.

RELATIONS BETWEEN MYRTLE AND KNOXVILLE.

The Myrtle formation takes its name from what is regarded as its typical exposures along Myrtle Creek, Oregon, in the Roseburg quadrangle. In this general area the maximum thickness of the Myrtle formation is estimated by Mr. Diller to be about 6000 feet. It is separated on paleontological grounds into two portions, the later (upper) of which from its contained invertebrate fauna was correlated with the Horse-town of California, while the earlier (basal) portion was correlated with the Knoxville on the basis of the presence of certain invertebrates but especially *Aucella crassicollis* and

* Science, N. S., vol. xxx, pp. 347, 348, Sept. 10, 1909.

Aucella Piochii. The first mentioned species of *Aucella*, Mr. Diller says,* “is characteristic of the later portion of the *Aucella*-bearing beds immediately adjoining the Horsetown beds. In California these forms are found in the Knoxville beds, which lie below and are older than the Horsetown beds.”

In his latest published words on the relations of the Myrtle formation Mr. Diller continues as follows:† “At the base of the ‘Myrtle formation’ in Oregon there is an important unconformity and overlap. The successively newer, overlying strata of the ‘Myrtle’ in general lap over further and further inland beyond the limit of the older strata of the same series, just as the members of the Shasta series do in California. Furthermore, the lower portion and greater part of the ‘Myrtle formation’ is characterized by a fauna in large measure identical with that of the Knoxville beds, while the top part contains a fauna closely related to that of the Horsetown beds. There is good reason, therefore, for regarding the Shasta series of California and the ‘Myrtle formation’ of Oregon as equivalent.”

To this statement there is but one conclusion possible, namely—that Mr. Diller regards the Myrtle as a whole as the equivalent of the Shasta as a whole, the latter naturally including both Knoxville and Horsetown. As the newer part of the “Myrtle formation” corresponds to the Horsetown, so the earlier part corresponds to the Knoxville. That this earlier portion of the Myrtle really corresponds to the whole of the Knoxville is shown, as at Elk River, Thompson Creek, etc., by the presence in it of a Jurassic flora, and *Aucella Piochii*, which latter is held to characterize the lower Knoxville. On the other hand, from the presence of *Aucella crassicollis* in association with the Jurassic plants in this earlier portion of the Myrtle, the whole of this portion is held by some to be equivalent to the upper part of the Knoxville just below the Horsetown—in other words, that there is nothing in the Myrtle section corresponding to the middle and lower portions of the great Knoxville section. This view would seem to involve some paleontologic, as well as stratigraphic, difficulties or anomalies. First—If the lower portion of the Myrtle corresponds only to the upper part of the Knoxville, then it is hardly correct to say that the Myrtle as a whole is the equivalent of the Shasta as a whole. Second—As already pointed out, Louderbach, on structural and lithologic grounds, regards the lower portion of the Myrtle as referable to the Franciscan of California. To correlate this with the upper part of the Knoxville would certainly do violence to this view. Third—

* Roseburg folio, No. 48, p. 2, 1898.

† Geol. Soc. Am., Bull., vol. xix, p. 396, 1908.

A choice must be made between the evidence afforded by the two species of *Aucella*, since these are regarded as the most important and characteristic of the invertebrates. If *Aucella crassicollis* is selected, then this portion of the Myrtle will be upper Knoxville; if *Aucella Piochii* is followed, this portion may be lower Knoxville. In this connection it is to be remembered that in certain sections of the Myrtle—such, for instance, as that at Elk River—*Aucella crassicollis* occurs above, commingled with, as well as below, the Jurassic plants, while here or in nearby areas *Aucella Piochii* is found also below, with and above the plants.

In view of these conflicting alternatives it seems to the writer that the plants, being thoroughly consistent, afford the better criteria, and on their evidence the earlier portion of the Myrtle is regarded as representing the Jurassic portion of the Knoxville as a whole. If this be true, and it is believed to be, then *Aucella crassicollis* ranged from near the base of the Knoxville (Myrtle) to near its top.

As affording a possible confirmation of the position above assigned the Myrtle on the basis of the plants, a word may be said regarding a comparison of the depositional conditions under which the Myrtle and Knoxville were laid down. It needs but a glance at the geological folios involving the areas covered by the Myrtle formation (Port Orford, Coos Bay and Roseburg quadrangles) to show that during Myrtle time there was a broad bay, or estuary, opening on the west to the Pacific ocean, and extending northeast as far at least as the middle of the Roseburg quadrangle. In the Sacramento valley in Knoxville time there was similarly a bay opening on the south and extending northward between the Coast Range and the Sierra Nevada. In both areas there was a progressive subsidence and decided overlap. In the Myrtle area this extended northeast and was most marked in the Riddles area. In the Sacramento Valley it of course proceeded northward, first the Knoxville, then Horsetown, and finally Chico, resting successively on older rocks. So far as known to the writer there is no *a priori* reason why these two bays may not have been practically synchronous. It will probably never be possible to settle this point stratigraphically, since it is highly improbable that these were at first, if indeed ever, connected on the present land mass.

That the Myrtle formation, as thus far made known, corresponds only to the upper part of the Knoxville, while the still earlier lower portions are concealed beneath the sea, or may yet be found in some unexplored portion of Oregon, is to beg the question.

RELATIONS BETWEEN KNOXVILLE AND MARIPOSA.

The evidence that has been presented regarding the Jurassic flora and its distribution obviously has a bearing on the relations between the Knoxville and the Mariposa. As is well known, Dr. C. A. White held that the Knoxville and Mariposa were contemporaneous, at least in part, a view fully accepted by Doctor Becker, though not generally agreed to by subsequent workers in this field. The two formations have never been found in contact, nor are they likely to be, since one (Mariposa) is found on the western slope of the Sierra Nevada in central California, and the other (Knoxville) on the opposite side of the Sacramento Valley, mainly against the eastern slope of the Coast Range. A strong point of agreement is shown by the abundance of *Aucellæ* in both, though they are not now admitted to belong to a single species, as Doctor White believed. Doctor Stanton states that "the faunas, though not large, are entirely distinct, and that of the Mariposa includes several forms of ammonites that are characteristic of late Jurassic the world over, while that of the upper part of the Knoxville contains an equally characteristic array of Cretaceous forms." It is not surprising that there should be a marked difference between the fauna of the Mariposa and the *upper part* of the Knoxville, but when the comparison is made with the lower Knoxville, according to Prof. James Perrin Smith, it shows "a fauna closely related to that of the Mariposa, still with Jurassic types of *Aucella*." As a matter of fact practically the entire Knoxville fauna, with the exception of *Aucella*, has come from the upper 3,000 feet of beds, that is the beds within this distance of the upper range of *Aucella crassicollis*, which is fixed as the point separating Knoxville from Horsetown. As thus delimited it comprises a sufficiently distinct faunal group (the Paskenta division of Anderson), but its extension to include the underlying 17,000± feet of beds which contain exceedingly few of the Knoxville species other than *Aucella*, is seemingly without adequate support.

Be this as it may, the relation, if it exists, is through the flora of the Monte de Oro formation near Oroville, which "on geographic and structural as well as lithologic and economic grounds" has been correlated with the Mariposa. The Oroville flora, as already shown, binds it inseparably with the other Jurassic plant-bearing areas in California and Oregon, and as pointed out on p. 49, the finding of five characteristic Oroville plants in the Middle Jurassic of the Cook Inlet region is certainly a strong indication that the Mariposa (Monte de Oro) is not the latest Jurassic.

The intense folding, vulcanism and partial metamorphism of the Mariposa is held to be a strong indication of its greater age as compared with the Knoxville, where there has been comparatively little folding or other alteration; yet even this should apparently be accepted with a measure of caution, since it is by no means clear that the various students who have worked in this field have always given the same limits to the Knoxville. Thus the Dillard area of Oregon seems to be more or less of an exception. In this area the rocks have undergone silicification and veining similar to that of the Mariposa, and on these lithologic as well as other grounds are regarded by Louderbach as identical with the Franciscan of California, which is almost certainly the approximate equivalent of the Mariposa, if not indeed below it. However, from the presence in the rocks of the Dillard area of two species of *Aucella* (*A. Piochii* and *A. crassicollis*), Diller considers them referable to the Myrtle (Knoxville). But since the shells occur in calcareous pebbles in a conglomerate it is possible that they were derived from an earlier *Aucella*-bearing horizon, though it is but fair to state that Diller concludes that they may be concretions rather than true rolled pebbles.

RELATIONS BETWEEN DOTHAN AND MARIPOSA.

In the Oregon areas here considered the Jurassic plant beds are unconformably underlain in many places by rocks to which the name Dothan formation has been given, and these in turn have been tentatively correlated with the Franciscan of California. The Dothan rocks, chiefly sandstones with some slates, which have been more or less silicified and veined, are characterized by the presence of *Aucella Erringtoni*, a species found also in the Mariposa. The only plant thus far noted in the Dothan was found on Catching Creek, about six miles southwest of Riddles, and was identified as probably the upper part of a leaf of *Pterophyllum*, such, for example, as *P. æquale* (Brongn.) Nath. Although this is so fragmentary as to be of little value in fixing the age, it is nevertheless a suggestion that if a flora could be developed in these beds, it would more than likely bring out a similarity to that of the Oroville (Monte de Oro) flora.

THE LINE BETWEEN THE JURASSIC AND THE CRETACEOUS.

It has been held on structural and stratigraphic grounds, that in this area the line between Jurassic and Cretaceous should be drawn at the base of the Knoxville. However, the paleobotanical evidence that has been presented in this paper shows that, notwithstanding the unconformable relations existing between the Knoxville and underlying beds, this is not a

natural line of delimitation. According to the plants the major portion of the great Knoxville section was deposited in Jurassic time, and the line should be drawn through the upper Knoxville at the highest point (about $2000 \pm$ feet below the summit) at which the Jurassic flora occurs. This point corresponds very nearly with the upper limit of the range of *Aucella Piochii*, which is acknowledged to be of Jurassic type, and, as already shown, extends down into the horizon of the Mariposa. It is true that this places the line at a point where there is no evidence of a break in the sedimentation, but it is a very decided paleontological break, and is exactly similar in character to that relied upon to separate Knoxville from Horsetown in the same section. Although the Knoxville is of such great thickness (20,000 feet), it is not probable that it required a very long time, geologically speaking, for its deposition.

SUMMARY.

1. The Lower Mesozoic strata of Oregon and California have afforded two floras, one of which is Cretaceous and the other Jurassic. These two floras, although sometimes occurring practically in the same section, have not been found commingling.

2. The Cretaceous flora ranges from the extreme upper part of the Knoxville formation through the Horsetown formation. It embraces about 60 species of plants and is regarded as being of Lower Cretaceous (Neocomian) age. It finds its closest affinity with the Kootenai of the Interior region, the Trinity of Texas, and the lower Potomac of the Atlantic Coast.

3. Associated with the Lower Cretaceous flora is an invertebrate fauna regarded as being of Neocomian age, the plants and invertebrates thus being in agreement.

4. The Jurassic flora, which has been called the "Jurassic flora of Oregon," ranges from beds which have been referred to the Mariposa formation, through the major portion of the Knoxville formation. It includes 100 species and finds its close affinity with the Lower Oölite floras of known position in other parts of the world. It is beyond question a true Jurassic flora.

5. Associated with the Jurassic flora is a meager, often poorly preserved, invertebrate fauna of only seven species, including the two supposedly characteristic species of *Aucella* (*A. crassicollis* and *A. Piochii*). This fauna, with the exception of *Aucella Piochii*, is the same as that found in association with the Lower Cretaceous flora, and it is on account of this association that the Jurassic plant beds have been referred by some invertebrate paleontologists to the Cretaceous.

6. The age of the beds containing the "Jurassic flora of Oregon" thus hinges on the relative strength of the evidence afforded by the flora as compared with that of the associated fauna. It has been shown in this paper that of a total of 100 species of plants, 47 species are known also from known Jurassic of other, often widely separated, parts of the world. Only one of these 100 species has been found in the Lower Cretaceous beds of the region. The total Knoxville fauna comprises 77 forms of invertebrates, only 7 named species of which have been found associated with the Jurassic plants. Of these 7 species of invertebrates, only a single species has been found outside the limits of the Oregon-California area, and it has been further shown that the invertebrate paleontologists are not in accord among themselves as to the interpretation to be given the age determination of the fauna. The conclusion is reached that the plants, being thoroughly consistent, afford the better criteria, and the beds are regarded as unquestionably of Jurassic age.

7. From the paleobotanical evidence which has been presented it follows that in this portion of the Pacific Coast region the line between the Jurassic and Cretaceous is to be drawn through the upper part of the Knoxville formation, and not at its base. This line is fixed by the upper limit of the Jurassic flora.

ART. V.—*Geologic Bearing of the Peat Beds of Anticosti Island*; by W. H. TWENHOFEL.

[Contributions from the Paleontological Laboratory of Yale University.]

Introduction.

INFERENCES as to the method of deposition of the vegetable matter forming coal have developed two rival hypotheses: the one arguing for deposition of the vegetable matter after transportation; the other for deposition by growth in place. The former hypothesis has had its ablest supporters in France, where the close association of coal beds with transported deposits and the character of the coal itself lend aid to that view. The latter hypothesis has been and is most favored in America, England and Germany. In many cases more extended studies have reduced in numbers the coal beds believed to have resulted from deposition after transportation.

The climate of coal-forming times has been a subject concerning which geologists have held and hold different views. Most that has been written on this question has sought to show that a luxuriant vegetation existed at such times and that such has required a warm climate for its development. From time to time doubt has been cast on that view, yet it apparently remains almost universally accepted at the present time.

It is the purpose of this article to endeavor to give additional facts bearing on the method of deposition of the coal and on the climate of past coal-forming times. The writer wishes to acknowledge his obligations to Professors Charles Schuchert and Joseph Barrell for advice and criticism in the preparation of the paper.

Coal beds in association with marine deposits and resting directly on limestones of marine origin have been reported from various portions of the coal fields of the United States,* but to the writer's knowledge practically nothing has been offered in explanation of the origin of such formations. In the case described by Winslow the coal is of the cannel variety, which is ordinarily assumed to have been deposited by water in a quiet basin and subjected to prolonged leaching;† but in this case it lies in an erosion channel. Coal beds of this character find a ready explanation, other facts being neglected, by deposition after transportation. Greater difficulty of explanation arises if a continental origin by growth in place be assumed.

In the following pages such a coal bed now forming will be described, and a brief discussion will be given of the conditions under which it is developing.

* 22d Ann. Rep. U. S. Geol. Surv., pp. 175, 181, 216, 1901. Winslow, Arthur, Prelim. Rep. on Coal, Mo. Geol. Surv., p. 170, 1891.

† Dana, J. D., Manual of Geology, 4th ed., p. 710, 1895.

While engaged in the summer of 1909 in studying, in the interest of the Peabody Museum of Yale University, the Ordovician and Silurian strata of Anticosti Island, the writer had his attention frequently attracted to the peat deposits which are forming on nearly all parts of the island's surface. This island is situated in the northern half of the Gulf of St. Lawrence between $49^{\circ} 4'$ and $49^{\circ} 53'$ north latitude. Its surface consists of a series of flat and poorly drained raised terraces which are backed by sea-cliffs of relatively recent age.

The examination covered the entire coastal portions and several parts of the interior, an area with a maximum length of one hundred and forty miles and a maximum width of a little more than thirty-four miles.

Description of the Deposits.

The Peat.—The peat deposits of this island, said to be the greatest in Canada,* are practically coextensive with the island's surface. Thicknesses vary from two to ten feet, the minimum thicknesses existing on the slopes of the upland areas where the drainage is best and where decay has advanced farther so that more earthy matter is present. The maximum thicknesses and best quality are found on the lowest terrace and flat, or nearly flat, portions of the higher terraces. On many areas the peat is very black, well compressed and of good quality, showing microscopically few traces of the original vegetation. On other areas it is less compact, of a more or less brown color, and much undecayed matter is present. Both varieties often exist in the same bed and woody matter may range from top to bottom.

On the eastern two-thirds of the south coast for about eighty miles the lowest terrace is two or more miles wide and here the peat reaches its greatest development as a thick deposit, thicknesses of more than ten feet being common. Numerous other areas of from one hundred to more than a thousand acres, where a thickness of about ten feet exists, occur at all altitudes.

In many places the surface of the peat beds is marked by low ridges and hillocks and in the lower portions of such beds undulations duplicating these appear, but somewhat more gentle in outline. Such are well shown in the vicinity of Chaloupe Creek, about sixty miles from the east end of the island, where on cross-section a ripple-mark effect is produced. It is believed that the irregularities of the upper surface are produced by differential growth of vegetation, these irregularities under compression tending to flatten out.

Substratum of the Peat Beds.—The substratum on which the peat rests consists of Ordovician and Silurian limestones

* Logan, W. E., Rep. of Progress, Can. Geol. Surv., p. 783, 1863.

and shales with an approximately level eroded surface, the beds dipping southward from less than one to about six degrees. Lying upon these strata in limited areas, but so far as known to the writer, on the south side only, are stratified beds of Pleistocene or more recent clays that are of marine origin, as indicated by the presence of *Mya arenaria* in abundance. A small angular unconformity, difficult to determine on small exposures, separates the two deposits.

Overlying portions of these clay deposits conformably, so far as known, are beds of stratified sand and gravel ranging in some places up to more than fifty feet in thickness and holding at different horizons lenses of clay. In some localities the sand apparently rests on the limestones. Pebbles and bowlders of glacial origin are present in both clay and gravel.

Overlying the clay, gravel, and sand, and the limestones where these are wanting, is a thin veneer of limestone gravel, which is apparently of beach origin. Overlying this are the peat beds producing another unconformity. These two unconformities would, after burial, be difficult to detect at small exposures, unless such were transverse to the old cliffs, and fossil evidence would be the chief criterion for their determination.

Marine Fossils in the Peat Beds.—On the lowest terrace, shells of marine organisms, such as sea-urchins, fragments of lobsters and crabs, gastropods, etc., are exceedingly common; being brought there by birds, chiefly crows, and more rarely, but in greater numbers, by waves of storms. Many examples of the latter case can be seen at different points along the south shore, where hundreds of sea-urchins have been washed upon the seaward edge of the marsh.* These must exist in the peat beds of the lowest terrace, and as each of the higher terraces at one time held the position of the now lowest terrace, they should also be found in them although none were seen.

Conditions of Formation.

Character of the Vegetation.—The conditions that have permitted the development of these extensive peat deposits without an underlying soil are due to a combination of conditions none of which are uncommon. The greater portion of the island is covered with a low, dense, chiefly coniferous forest growth, so dense in many places as to be almost impenetrable. The absence of a soil does not permit the trees to gain a firm foothold, while the vast amount of water in the substratum has forced a horizontal development of roots. The foothold of the trees is, therefore, in most cases a very precarious one. The result is that the winds, always prevalent and usually strong, blow most of them down before a great height is

* On the marsh about six miles west of Chaloupe Creek bushels of the common sea-urchin (*Strongylocentrotus dröbachiensis*) were seen.

attained unless they occupy more or less sheltered areas. The writer has seen one locality where fully a dozen half-grown trees had gone down together, the entire substratum being uplifted as a floor. In a wind this substratum can be felt to heave underneath one's feet.

Some areas of the lowest terrace are treeless, the vegetation in most cases consisting of mosses, grasses, orchids, ground-pines, and similar low plants. Other treeless areas have a tangled growth of procumbent and low shrubs which are penetrable with the greatest difficulty. Among such shrubs a low spreading conifer is especially prominent, in many places effectually shielding even cliff slopes from the sun. Portions that are more or less covered with water are not lacking in a heavy growth of vegetation.

The rank luxuriance of the vegetation was a source of surprise. The annual growth rapidly springs up in wonderful profusion, while an open forest growth is not favored, due to the elimination of most of the large trees. This annual growth is added to the peat in the early part of September in a relatively short period of time and at a time when the absence of heat and superabundance of water prohibit oxidation. The writer believes that too great emphasis cannot be placed upon the fact that here in a relatively cold climate there exists a heavy annual growth of vegetation which is yearly added to the deposits of peat under conditions that practically prohibit its oxidation.

A comparison with the vegetation of such tropical regions as are exemplified by the Amazon valley would show that at any one time a greater quantity of vegetation exists in a definite region than exists on an equal area of Anticosti; but it is questionable if such a great increment is annually given to the substratum in the former region as in the latter, while in the former region the death of the vegetation extends over a long period of time under conditions that permit its ready destruction. The point upon which emphasis is desired to be laid is not, however, the abundance of vegetation; but the quantity that is not oxidized.

Climatic Conditions.—The climate is cool and moist. The temperature varied in the six years extending from 1897 to 1902* from 26° C., which occurred once, to -39° C., which occurred twice. The average temperature of June, July, and August is about 12·5° C.; that of the winter months is about 10° C. in the negative sense. The average annual temperature is about 2° C.†

* Schmitt, Joseph, *Monographie de l'île d'Anticosti*, pp. 40-43, Paris, 1904.

† Ham, J., *Isotherms of North America*, Bartholmew's Physical Atlas, pl. 7, 1899.

The precipitation in the form of rain in the three months of the growing season varies from twenty-three to twenty-eight centimeters.* This does not appear to fall in a few heavy downpours, but in small quantities and often. The mean annual rainfall lies between fifty and one hundred centimeters, but is nearer the latter figure.† The snowy precipitation ranges from an average of three feet at the west end to about two feet at the east end.‡ Cloudiness and fogginess often prevail. The island lies in that region of North America that has the second highest per cent of clouded sky. The mean annual sunshine consists of less than 1750 hours.§ Fogs are extremely common on the east and south sides, as is shown by the fact that Mr. Emile Laprise, the South Point light-keeper, sounded the fog alarm on twenty-six days in July, 1909.

The water is collected in the numerous lakes and ponds, which abound everywhere from the lowest to the highest levels, as well as in the bogs and vegetable deposits. The falling water is absorbed by the substratum and little immediate flow results to swell the creeks and rivers, which were at no time seen in a muddy condition. They have, however, a steady permanent flow. Nearly every rock outcrop is a spring. At the old and new sea cliffs nearly every joint and many bedding planes are pouring forth water, a fact which will be rather strongly impressed in the experience of any one who attempts to collect fossils from these cliffs.

During more than seven months of the year the whole is ice bound; during the remainder of the year, except the early spring time before the annuals appear, the whole is effectually shielded by the profuse growth of annuals aided by the ever-green cover. Oxidation cannot occur, or at least is extremely limited, during the summer season and is hardly possible when the whole is ice bound and covered with snow.

Topographic Conditions.—The island's surface has been described as a series of flat, wave-cut terraces.¶ This level floor has favored the development of undrained areas. The highest terrace, which is more or less dissected, has an elevation above three hundred and fifty feet; the lowest is between eight and fifteen feet above high tide. Inferences as to the possible increased future extent of the deposits may be founded on the following facts: The island is surrounded by a wave-cut terrace upon which vegetation is wanting. This is now a part of the littoral, reaches a maximum width of more than two miles, and will average more than one-fourth mile. There

* Schmitt, *idem*, p. 50.

† Herbertson, A. J., *Bartholmew's Atlas*, pl. 18, 1899.

‡ Schmitt, *idem*, p. 51.

§ Van Bebber, J. W., *Bartholmew's Phys. Atlas*, pl. 18, 1899.

¶ This statement is known to be correct for the major portion of the island. In the extreme interior it may not be true.

is considerable evidence to show that the island is in a process of elevation with respect to sea level. Should this continue, vegetation will take possession of the then elevated terrace and a belt more than two hundred and eighty miles long with an average width given above will be given over to the formation of peat.

Inferences of Origin after Burial.

These deposits if entombed and metamorphosed into coal will contain land and marine fossils, the latter perhaps being greater in number; at least, remains of marine organisms are most often seen on the surface of the lowest terrace. They will lie between marine deposits from which they will be separated by unconformities representing great time intervals and difficult to detect except in sections transverse to the old sea cliffs. They will abut against these old cliffs, of whose origin there will be no question, and will have much appearance of having been deposited at their bases by transportation. Few trees will stand upright. Most will lie flat. Some may be found with roots upward. The biennial alternations of thawing and freezing will have macerated the leaves so that few perfect ones will remain. The helter-skelter and tangled masses of downfallen trees that are now common, if preserved, will simulate the appearance resulting from transportation. The undulations of the peat beds may even lead to the assumption that they are due to ripples. From another standpoint the profuse development of vegetation may be taken as evidence of a genial climate.

Conclusions.

The peat beds of this island and the magnificent growth of vegetation have strongly impressed on the writer the fact that a relatively cold climate may support a wonderful luxuriance of plant growth, providing the rainfall be sufficient, and that a warm climate is not an essential condition for the great accumulation of vegetable matter. This fact was recognized as early as 1835 by Darwin, who states: "In Terra del Fuego trees grow only on the hill-sides; every level piece of land being invariably covered by a thick bed of peat. * * * The climate of the southern part of America appears particularly favorable to the production of peat. In the Falkland Islands almost every kind of plant, even the coarse grass which covers the whole surface of the land, becomes converted to this substance; scarcely any situation checks the growth."*

From the polar side of the northern hemisphere Russell describes the tundra of the northern part of Alaska as covering "the whole surface, excepting the faces of steep cliffs and

* Naturalist's Voyage Round the World, 1835.

the summits of high mountains," and says that "a depth of 150 to 300 feet has been assigned to it where it is exposed in a sea cliff at the head of Kotzebue sound." He further states: "On the flood plains of the larger rivers and generally throughout all of Alaska, peaty deposits are forming in the same manner as on the tundra, modified, however, by the growth of arborescent vegetation and by the intrusion of sand and clay in places that are flooded during the high-water stage of the rivers." Russell suggests that such may have been the origin of some of our present coal deposits, which is further reinforced by the statement that the flora of the tundra is essentially cryptogamic and that "two species of *Equisetum* which may be considered as representing the Calamites of former times flourish in rank luxuriance over greater areas of the Yukon."*

Instances of enormous peat deposits in the polar halves of the temperate zones could be multiplied to great extent, while instances of such in the warmer regions are few or wanting, Schimper stating that peat does not form in the tropics except on mountains over 1200 meters high.†

Nor are examples confined to the present; for David notes the occurrence in New South Wales "of a group of Coal Measures, over 230 feet thick, and comprising from 20 to 40 feet in thickness of coal (the Greta Coal Measures)" being "sandwiched in between the erratic-bearing horizon of the Lower Marine Series and the similar horizon of the Upper Marine Series,"‡ while Chamberlin and Salisbury state: "The coal beds that lie between the glacial beds attained the usual thickness."§

It may be well to ask if such facts as the above do not have great bearing on the question of the climate of past coal-forming times. It would appear that a series of comparative studies on peats of tropical and polar climates, with particular attention paid to possible different physical characters of the plants composing them, might give data of importance that would serve as criteria for distinguishing coal of different climates.

A second conclusion that has been reached is that deposits of coal of continental origin may have many of the characters of marine deposits and that in interpretations of the origin of a coal bed, the absence of a fire-clay substratum, the presence of marine fossils, and great uprooting of trees are not necessarily conclusive evidence of marine origin nor even determining evidence against a continental origin by growth *in situ*.

* Russell, I. C., Bull. Geol. Soc. Amer., p. 99, 1890.

† Plant Geography (Eng. Trans.), pp. 381-382, 1898.

‡ Quart. Jour. Geol. Soc., London, p. 289, 1896.

§ Geology, 2d ed., vol. ii, p. 605, 1907.

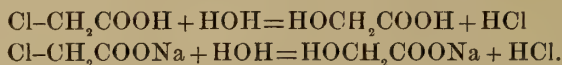
ART. VI.—*Hydrolysis of Esters of Halogen Substituted Acids*; by W. A. DRUSHEL and J. W. HILL.

[Contributions from the Kent Chemical Laboratory of Yale Univ.—ccxii.]

1. *Acetic Esters.*

A GREAT deal of attention has been given by chemists in recent years to the study of the velocity of hydrolysis of esters. Among others, acetic esters have been hydrolyzed under various conditions and the velocity of this reaction measured. In 1883 W. Ostwald* published the results of his experiments in determining the strength of different acids as shown by their catalytic action on the hydrolysis of methyl acetate. Later deHemptinne,† working under the direction of Van't Hoff, determined the rate of hydrolysis of a large number of esters, among them methyl, ethyl and propyl acetates. Löwenherz‡ later took up the subject and included in his studies the methyl and ethyl esters of chloracetic acid and the ethyl di- and tri-chloracetates. Since then Price§ has done some work in the same field, adding isobutyl acetate to the list of esters whose rates of hydrolysis have been measured. All of these investigators, with the exception of Ostwald, used hydrochloric acid as a catalyzer to aid the hydrolytic action of water. VanLaar|| determined the reaction when water alone was present.

The present work was undertaken to extend our knowledge of the effect on the rate of hydrolysis when the various halogens are substituted for hydrogen in the acetyl end of the ester molecule: It has been shown by Stentor,¶ Buchanan,** Kastle and Keiser,†† and others,‡‡ that the halogen substituted acids react with water and their sodium salts with water and sodium hydroxide, with the splitting out of the halogen and substitution of hydroxyl according to the equations:



Apparently no one with the exception of Löwenherz has investigated the behavior of the esters of the halogen substituted acids.

* J. prakt. Chem. (2), xxviii, 449. § Abs. Chem. Soc. (Lon.), xi, 528.

† Zeitschr. phys. Chem., xiii, 561. || Zeitschr. phys. Chem., xiii, 736.

‡ Zeitschr. phys. Chem., xv, 397.

¶ Proc. Chem. Soc., 1909, 236; Trans. Chem. Soc., 1907, 460.

** Ber. Dtsch. Chem. Ges., iv, 340, 1871.

†† Amer. Chem. Journal, xv, 471.

‡‡ Slator, Trans. Chem. Soc., 1904, 85 and 1291; 1905, 481.

In preliminary experiments, which were made to see if there is any splitting out of halogen in the course of the reaction, N/20 solutions of esters in N/20 acid were placed in the thermostat and titrated from time to time with N/10 silver nitrate solution, using an aqueous solution of potassium chromate as an indicator. In the case of the monochlor- and monobromacetic esters no increase in the free halogen acid was observed even after several weeks. The iodo-esters, however, were apparently decomposed with liberation of iodine, but whether through the decomposition of the acid set free by hydrolysis or directly from the ester we have not at the present time determined.* To prevent possible substitution of chlorine for bromine in the monobromacetic esters, hydrobromic acid was used as a catalyzer; as this has almost exactly the same strength as hydrochloric acid† used with the other esters, the difference in catalyzing effect is negligible. The chlorformic esters, which we had intended to include in our investigation, were rapidly decomposed with evolution of CO₂ showing total decomposition according to the following equation:



Preparation of Esters.—The methyl and ethyl acetates were prepared in part by the method of Phelps‡ and in part by the method of Thomsen.§ The propyl and isobutyl acetates were prepared by acting with acetyl chloride on the corresponding alcohol. This reaction is rapid and practically quantitative. The halogen substituted esters were generally prepared by the action of chloracetyl chloride and bromacetyl bromide on an alcohol. The methyl and ethyl esters of chloracetic acid, however, were prepared from chloracetic acid and alcohol by the method of Thomsen. The mixture of esters with the excess of acid and alcohol was neutralized with Na₂CO₃ and diluted by pouring into a large volume of water. The layers formed were separated and the ester was washed with water, dried over CaCl₂ and fractionated. The part boiling within 0.1° to 0.3° of the boiling point given in the literature was taken for the experiments.

The halogen substituted acetic esters are pungent compounds. When perfectly pure they are not disagreeable, but after hydrolysis or before purification their vapors are very irritating to the eyes and mucous membrane. As the vapors of the impure ester contain excess of acid and the mixture of acid and alcohol after hydrolysis have the same effect on the eyes,

* This point will be investigated by the authors.

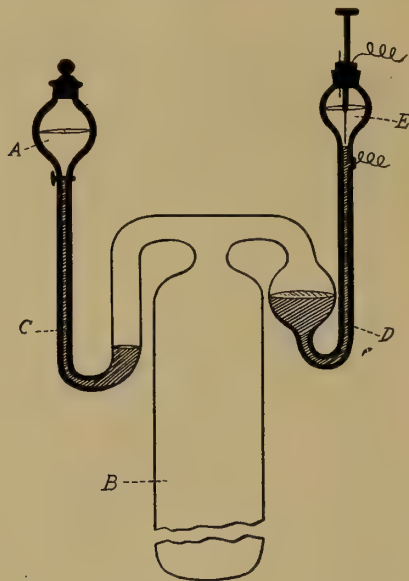
† Ostwald, *Zeitschr. phys. Chem.*, iii, 418.

‡ This Journal, xxiii, 368, 1907.

§ Thomsen's *Thermochemische Untersuchungen*, iv, 201.

this action is probably due to the presence of the halogen-substituted acetic acid.

The Thermostat.—The thermostat used is cylindrical in form, about 30 inches deep and 33 inches in diameter. It is built of tinned copper and covered with a half-inch layer of felt. It is supported on a heavy iron plate with a twelve-inch hole in the center. This plate rests on legs about eight inches above the floor so that one or more burners may be placed beneath. A coil of lead-pipe around the inner wall about half-way up, conducting steam or cold water, aids in rapidly chang-



THERMO-REGULATOR.

A and B, toluol; C and D, mercury; E, alcohol.

ing the temperature. For instance, when it is necessary to change from a temperature of 25° to one of 40° this pipe is connected with a steam pipe and steam heat is utilized. On the other hand, a slow stream of cold water enables one to work at a temperature below that of the room. When working at high temperatures the thermostat is covered with asbestos board to prevent radiation of heat from the large surface.

The thermo-regulator is of special pattern and allows the temperature to be changed at will. This apparatus, shown in the accompanying cut, consists of a vertical cylindrical bulb of 400cm^3 capacity filled with toluol. To the top of this bulb

two tubes are sealed. These curve downward for about six inches, then upward above the top of the toluol bulb, the downward portion consisting of 8^{mm} glass tubing and the upward portion of heavy capillary tubing. To the upper end of one of the capillary tubes is sealed a glass-stoppered bulb having a stopcock. A platinum wire is sealed into the other above the level of the water in the thermostat. To the upper end of this capillary tube is sealed an enlarged tube closed with a two-holed rubber stopper carrying an adjustable electrode terminating in a platinum wire. These electrodes are connected with a gas regulator of the Hahn type.* Mercury fills both capillaries and a portion of each of the larger tubes connecting the capillaries with the toluol bulb, the mercury columns being so adjusted that their weights balance each other, thereby preventing leakage of toluol at the stopcock. The tube with the adjustable electrode is filled with alcohol to prevent sparking. When it is desired to change the temperature of the thermostat, all that is necessary to set the thermoregulator is to open the stopcock of the bulb to allow the toluol to pass through and close it again when the proper temperature is reached. The final adjustment is made by raising or lowering the electrode by turning the screw. A Beckmann's thermometer, graduated to 0.01°, is set and clamped in the thermostat to indicate the temperature. Stirring is effected by means of a two-flanged stirrer mounted on ball-bearings and driven by a low speed motor, which is in series with the gas regulator and in parallel with a resistance. Rotary stirring is prevented by a rectangular copper plate fixed near the bottom of the thermostat and so placed as to direct the current upwards. The temperature can be maintained constant within $\pm 0.01^\circ \text{C}$.

Procedure.—In the case of the esters readily soluble in N/20 acid the amount required to make up a N/20 solution was weighed out in a small flask and dissolved in 250^{cm³} of the acid used which had previously been warmed in the thermostat to the temperature at which we were working. The mixture was then poured into pressure flasks and these were submerged in the thermostat to within an inch of their mouths. At first Erlenmeyer flasks of about 500^{cm³} capacity were used, but there was always more or less variation in concentration due to evaporation into the space above the solution and condensation on the colder upper surfaces of the flask. The smaller flasks had less vacant space and being well submerged condensation was prevented to a great extent.

At regular intervals a 25^{cm³} portion of the reaction mixture was withdrawn with a pipette and run into about 100^{cm³} of

* Zeitschr. phys. Chem., xliv, 525.

cold distilled water in a 300^{cm}³ flask. The pipette was allowed to drain 40 seconds and the time at the end of this period was recorded. As soon as possible the mixture was titrated with N/10 Ba(OH)₂ with phenolphthalein as an indicator. The end titrations were made on the contents of one of the flasks, usually after the lapse of a week. In the case of the less soluble esters a longer period was necessary before equilibrium was reached. Where N/20 solutions of the esters could not be prepared, saturated solutions were used. These were prepared by adding an excess of ester to the acid solution previously brought to the required temperature in the thermostat. After shaking vigorously for a few seconds the solution was rapidly filtered through a dry filter paper into pressure flasks and placed in the thermostat. This method was adopted to give a homogeneous mixture during hydrolysis.

In Table I are given results of individual experiments. Table II is a summary of the results obtained; the values of K given are averages of values for each experiment. Löwenherz's and deHemptinne's results calculated for 25° and N/20 acid are also found in Table II. Both used the formula

$$K = \frac{1}{t} \times \log \frac{A}{A-x} \text{ where } t \text{ represents time in 5-minute units,}$$

A represents initial concentration of the ester and A - x is concentration at the end of $t \times 5$ minutes. Löwenherz worked at 40° and deHemptinne at 25°; both used N/10 hydrochloric acid as a catalyzer. Therefore in calculating the former's results for 25° and N/20 hydrochloric acid, the following formula was used:

$$K = \frac{K \times 2.3}{3.8 \times 5 \times 2}$$

where K is the velocity constant for 25° and N/20 acid with one-minute time units, 2.3 is the factor to transform to natural logarithms, 3.8 is the coefficient for the temperature change 25° to 40° N/10 acid as found by Löwenherz. Throughout

our work the formula $K = \frac{2.3}{t} \times \log (T_a - t_o) - \log (T_+ - T_o)$,

which is the same formula expressed in terms of titrations, has been used. We have, however, expressed time in one-minute units and multiplied by 2.3 to convert ordinary logarithms to natural logarithms.

Löwenherz found experimentally that the temperature coefficient of N/10 hydrochloric acid for the change from 25° to 40° is 3.8. To obtain this he determined the reaction velocity constant for the same ester at 25° and at 40° and divided the

latter by the former. In the same way we determined the coefficient for N/20 hydrochloric acid for the temperature change from 25° to 35° and found it to be 2.0. For N/20 hydrobromic acid it has been found to be 1.7. For the range 25° to 40° hydrochloric has a coefficient of 3.0. These coefficients have been used in calculating some of the results for Table I.

On inspection of this table it will be seen that the rate of hydrolysis is lowered to a marked extent by the introduction of one atom of halogen, the chlorine substituted esters having the lowest rate. The contents of the acetates, chloracetates and bromacetates are to each other as 33 : 21 : 25.

Apparently the most favorable conditions for hydrolysis exist when both base and acid are weak.* In the hydrolysis of the acetic esters we have such conditions, for the alcohols are weak bases and acetic acid is a weak acid, giving a relatively large constant. Chloracetic acid is a stronger acid and the rate of hydrolysis is correspondingly lower. Bromacetic acid is not so strong as chloracetic but much stronger than acetic acid† and its esters are found to have constants slightly larger than those of the chloracetic esters but smaller than those of the acetic esters. The nature of the alcohol seems to have little effect on the rate of hydrolysis.

TABLE I.

Methyl Acetate 10 ⁵ × K		Methyl Chloracetate 10 ⁵ × K		Methyl Bromacetate 10 ⁵ × K	
25° and .05N HCl		25° and .06N HCl		25° and .05N HBr	
				I	II
33.8		25.8		26.4	24.7
29.5		27.0		26.6	25.3
33.5		25.2		26.2	24.6
33.5		27.0		25.5	
33.2					
35.0					
Mean 33.0		Mean 26.3		26.0	—Mean— 24.8
Ethyl Acetate		Ethyl Chloracetate		Ethyl Bromacetate	
				25° and .05N HBr	
I	II	25° and .094N HCl		I	II
25° and .05N HCl	40° and .123N HCl				
30.1	248.	39.8		24.4	23.6
28.0	224.	35.0		23.1	24.6
30.3	272.	36.2		23.8	23.3
31.5	229.	40.8			
29.3		38.9			
29.8 —Mean—		Mean 38.9		23.8 —Mean—	

* Nernst, Theoretical Chemistry, p. 521.

† By inversion of cane sugar Ostwald found acetic acid has value of .004 and chloracetic acid .048 that of hydrochloric acid. From determinations of affinity constants he found that chloracetic and bromacetic acids have values near to each other, viz., 0.155 and 0.138. See Jour. prakt. Chem. (2), xxix, 385, 1884. Also Zeitschr. phys. Chem., iii, 418.

Propyl Acetate		Propyl Chloracetate		Propyl Bromacetate	
I	II	I	II	I	II
40° and ·123N HCl	40° and ·08N HCl	25° and ·05N HCl	40° and ·08N HCl	25° and ·05N HBr	40° and ·08N HBr
220·	201·	20·4	93·0	26·9	134·
239·	160·	18·6	99·0	26·9	110·
228·	160·	19·5	92·0	25·3	
		22·9			
229· -Mean- 173·		20·7 -Mean- 95·0		26·3 -Mean- 122·	
Isobutyl Acetate		Isobutyl Chloracetate		Isobutyl Bromacetate	
I	II	I	II	I	II
25° and ·066N HCl	25° and ·066N HCl	25° and ·05N HCl	35° and ·05N HCl	25° and ·05N HBr	35° and ·05N HBr
44·3	46·7	22·5	43·5	25·4	41·3
44·8	43·5	20·3	43·5	22·5	40·9
42·1	43·8	21·4	42·6	26·3	40·3
45·0	43·4	21·2	41·6	24·0	42·4
44·4	44·5	21·6	45·1	26·0	40·7
43·5 -Mean- 44·3		21·4 -Mean- 43·3		24·7 -Mean- 41·2	

TABLE II.

Mean values of Table I calculated for 25° and N/20 acid.

	Methyl 10° K	Ethyl 10° K	Propyl 10° K	Isobutyl 10° K	Mean of series 10° K
Acetate	33·2	30·3	31·0	32·8	32·6
	35·0	32·9	34·0	33·4	
	33·3*	33·7*	33·4*		
Monochlor- Acetate	20·1	21·3	20·7	21·4	20·8
	21·8†	19·9†	19·7	21·4	
Monobrom- Acetate	26·0	24·8	26·3	24·7	25·0
	24·8	24·4	25·0	24·7	

* Calculated from deHemptinne's work; Zeitschr. f. phys. Chem., xiii, 561.

† Calculated from Löwenherz's work; Zeitschr. f. phys. Chem., xv, 397.

Summary.

1. The esters of monochlor- and monobromacetic acid show no tendency to decompose with liberation of halogen in aqueous solutions of hydrochloric and hydrobromic acid. Esters of iodine substituted acetic acid in hydriodic acid solution liberate iodine either from the acid set free or from the ester itself.

2. The rate of hydrolysis depending chiefly on the nature of the acid in the ester, is lowered by introduction of halogen in the acid. The acetic, chloracetic, and bromacetic esters of the same alcohol have constants which are in the ratio 33 : 21 : 25. The esters of the different alcohols and any one acid differ but little in the velocity of this acid hydrolysis reaction.*

3. The temperature coefficient for ·05N hydrochloric acid used as a catalyzer for the temperature interval of 25° to 35° is 2·0; for 25° to 40° it is 3·0; for ·05N hydrobromic acid it is 1·7 for the interval of 25° to 35°.

* This has been shown also by the work of Julius Meyer and others, see Zeitschr. phys. Chem., lxvi, 81-125.

SCIENTIFIC INTELLIGENCE.

I. CHEMISTRY AND PHYSICS.

1. *A Quantitative Reagent for Iron and Copper.*—In recent years various organic products have come into use as reagents for precipitating metals in quantitative analysis. One of the latest of these is nitroso-phenyl-hydroxylamine, $C_6H_5N(NO)OH$, introduced by Baudisch for the precipitation of ferric iron and copper. The ammonium salt of this base is an article of commerce under the name "Kupferron." BILTZ and HÖDTKE have put the reagent to test and have obtained very satisfactory results. In the precipitation of iron a large amount of acid, either hydrochloric, sulphuric or acetic, may be present; even 20° of concentrated hydrochloric acid in 100° of solution does no harm. The reagent was used in 6 per cent solution, being added at room temperature with stirring. The end of the precipitation is readily observed by the formation of a white precipitate of the base itself following the reddish brown iron precipitate. It is recommended to use an excess of about a fifth of the reagent. After 15–20 minutes the precipitate may be filtered on paper, preferably with suction, washed with water at room temperature until the acid is removed, then with strongly ammoniacal water to remove the excess of reagent, and then again with water. The ignition requires some care to prevent loss. Excellent results were obtained in this way in the determination of iron in the presence of aluminium, nickel, and chromium, where in extreme cases as much as 50 parts of each of these metals to 1 part of iron were present. The fact that these separations can be made makes the method a valuable one.

For the determination of copper with this reagent a large excess of mineral acid is to be avoided, and acetic acid appears to be best. Otherwise the operation is the same as for ferric iron, except that the excess of reagent was removed with 1 per cent sodium carbonate solution. Good results were obtained in separating copper from 10 parts of zinc using acetic acid solution, but for the separation of copper from cadmium it was found necessary to use dilute mineral acid solution. Attempts to separate iron and copper by precipitating both together and dissolving out the copper compound on the filter with ammonia gave slightly high results for the iron.

As far as the experiments have gone, it appears that iron and copper cannot be separated from silver, mercury, lead or tin, as these metals are also precipitated.—*Zeitschr. anorg. Chem.*, lxvi, 426.

H. L. W.

2. *The Detection and Determination of Very Minute Quantities of Silver.*—The estimation of very small quantities of silver is of importance particularly in connection with atomic weight

determinations, where it is necessary to take into account even the amount of silver chloride dissolved in cold water. G. S. WHITBY of the Royal College of Science, in London, has found a very delicate reaction for this purpose, which consists in adding sodium hydroxide and an organic substance, preferably cane sugar, to the silver solution and heating. He takes 50^{cc} of the liquid, adds a drop of rather strong sugar solution, places the 150^{cc} beaker containing the liquid in a boiling water bath for 2 minutes, then adds 6 drops of a normal solution of sodium hydroxide, and heats for 20 or 30 seconds longer. The yellow color produced, which appears to be due to colloidal silver, is now put into a Nessler tube and compared with colors produced in the same way from known amounts of silver. The colors are accurately proportional to the quantities of silver present, and in this way it is possible to determine 0.000002 g. of the metal in 50^{cc}, or 0.00004 g. in a liter. The author considers the delicacy of the reaction to be about the same as that of the nephelometer method of Richards and Wells, but he thinks that it is more easily and quickly carried out, and involves no complications.—*Zeitschr. anorg. Chem.*, lxvii.

H. L. W.

3. *Beryllium Formates*.—It has been found by S. TANTAR that when beryllium carbonate is dissolved in an excess of formic acid the normal formate $\text{Be}(\text{CHO}_2)_2$ is formed, which is stable upon evaporating the liquid even at a temperature of 100–110° C. This behavior is entirely different from that of the acetate, propionate and isobuturate, which are all basic salts corresponding to the acetate $\text{Be}_4\text{O}(\text{C}_2\text{H}_3\text{O}_2)_6$, even when anhydrous acids are employed and the evaporation is carried out at a low temperature, and in order to obtain normal salts of these acids it is necessary to heat the basic salts in sealed tubes with mixtures of the anhydrous acids and their anhydrides. The normal formate, however, is partly hydrolyzed with the formation of a basic salt upon boiling with water, and when the dry salt is heated under a diminished pressure of 30–35^{mm} decomposition takes place and the basic salt $\text{Be}_4\text{O}(\text{CHO}_2)_6$ sublimes. Another organic salt of beryllium is thus added to the list of its remarkable compounds which volatilize without decomposition. This basic salt was prepared in another way, by boiling a solution of the normal formate with the calculated quantity of the carbontate.—*Berichte*, xliii, 1230.

H. L. W.

4. *A Recalculation of the Atomic Weights*; by FRANK WIGLESWORTH CLARKE. 8vo, pp. 548. Washington, 1910. Published by the Smithsonian Institution.

This is the third edition, revised and enlarged, of Dr. Clarke's well-known work, which first appeared in 1882. There is no doubt that the previous editions, in making manifest the imperfections of many of the data, and in pointing out in what direction new work was needed, have had a most important influence upon recent activity in atomic weight research. This recent work has been so extensive and important, particularly that of

Richards and his pupils, that the present edition has been made necessary.

The clear view that this book gives of all atomic weight investigations, and the impression given of the most laborious calculations and the most painstaking conclusions, are its important features. The author has followed his original plan of subjecting all the data, unless they are clearly defective, to a mathematical treatment according to their probable errors. In this treatment most of the older work has practically no influence upon the final results, although in some instances older work seems to have too great an effect upon modern work that is probably freer from constant errors. It is probable that Dr. Clarke's method must be abandoned eventually in favor of using only the most accurate modern results in calculating the atomic weights, but more work appears to be needed before this can be accomplished satisfactorily. In any case the present work is most useful and important.

H. L. W.

5. *Pressure of Light on Gases*.—PETER LEBEDEW calls attention to a paper by J. Kepler, "De Cometis Augustæ Vindelicorum, 1619," in which the author comes to the conclusion that the repulsion of comets' tails by the sun is due to a pressure exercised by the light rays. Lebedew also discusses a paper of Fitzgerald, who working on Maxwell's well-known calculation of light pressure, calculated the magnitude of this pressure on the supposition that each gas molecule behaved like an absolutely black sphere under light pressure as black spheres of much larger dimensions. Lebedew quotes recent investigators to show that no restrictions are necessary to the theory that the gas molecule behaves as an absolutely black body, and he proceeds to measure the effect of light pressure, which Kepler was the first to predict—which Maxwell calculated—which Lebedew showed by investigation, and which Arrhenius has made the basis of a wide generalization in cosmical physics. The results of Lebedew's investigation are as follows :

(1.) The existence of the pressure of light on gas is shown experimentally.

(2.) The pressures are directly proportional to the quantity of energy impinging and to the absorption coefficients of the gas.

(3.) Within the faults of observation Fitzgerald's contentions are shown to be true.—*Ann. der Physik*, No. 7, 1910, pp. 411-437.

J. T.

6. *Coharers*.—Dr. W. H. ECCLES examines the subject of coharers, mathematically and experimentally, and puts forward the hypothesis that the properties of an oxide coherer "may arise solely from the temperature variations caused in the minute mass of oxide at the contact by the electrical oscillations and by the applied e.m.f.—*Phil. Mag.*, June, 1910, pp. 869-888.

J. T.

7. *Measurement of High Pressure*.—The Reichenstalt at Charlottenburg continues its work on the measurement of pressure by

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the change of resistance in manganine wire under pressure. The measurements show that the change is a linear one up to the limit employed, that of $800 \text{ k}_g/\text{cm}^2$. Dr. Bridgeman has shown in the Jefferson Physical Laboratory that the change is linear up to 11,000 atmospheres.—*Zeitschrift für Instrumentenkunde*, May, 1910, p. 154. J. T.

8. *Radiochemistry*; by A. T. CAMERON. Pp. viii, 174, with 3 portraits and 15 figures. London, 1910 (J. M. Dent & Sons).—The author says in his preface: "The book is intended to be of use to those who, having some knowledge of chemistry and physics, wish to know accurately the facts and theories of the subject at the present time; it is also intended as an introduction for others who wish to master the subject in its entirety."

After having read the book through carefully the reviewer has been unable to avoid the unpleasant conclusion that the author has distinctly failed to attain the ideals set forth in the preceding quotation. A few, typical illustrations may serve to justify this adverse criticism. In the first place, the book contains many errors in physics: On pages 17 and 90 the incorrect formulæ

" $I_0/I_t = e^{-\lambda t}$ " and " $v_0/v_t = e^{-\lambda t}$ " occur respectively. The

former equation leads to " $2 = e^{-\lambda t}$," (page 18), which means that a *negative* time is required for the activity to fall to half value. The accepted definition of the direction of an electrical current is violated on page 22. On page 26 the following remarkable sentence may be found: "The secondary rays, occasionally called δ -rays, also travel in straight lines, and otherwise obey the light laws, but are deflected by a magnetic field." On page 94 we read: "Ultraviolet light (*i. e.*, electrons) decomposes water. . . ." On the other hand, the book abounds in infelicities of expression which may be charitably ascribed to careless proof-reading.

H. S. U.

9. *Acht Vorlesungen über Theoretische Physik*; von Dr. MAX PLANCK. Pp. 127. Leipzig, 1910 (S. Hirzel).—These lectures by the distinguished professor of theoretical physics in the University of Berlin were given at Columbia University last year. The first two lectures deal with the fundamental distinction between reversible and irreversible processes, and with the application of thermodynamics to dilute solutions. The third and fourth lectures are devoted to the atomic theory of matter and to the connection between this theory and the empirical principles of thermodynamics. In the two following lectures the theory of "black-body radiation" is developed; this is a subject in which Planck was a pioneer and these two lectures contain a masterly presentation of a very difficult problem and of the progress which has been made toward its solution. In the seventh lecture, the general application of the Principle of Least Action to all reversible phenomena is discussed; and the last lecture contains a very clear and enthusiastic exposition of Einstein's Principle of Relativity. All the lectures are marked by

the lucidity and conciseness which are characteristic of the author. They form an admirable résumé of the present state of theoretical physics and will be read with pleasure and profit by any student of the science. There is perhaps a tendency toward dogmatism in regard to the philosophical interpretation of certain results; but the class of readers to whom the book is addressed will have a sufficiently wide knowledge of the subject to escape the danger of overlooking other points of view.

H. A. B.

10. *The National Physical Laboratory. Report for the Year 1909.* 103 pp., with 2 plates. Teddington, 1910 (W. F. Parrott).—The annual report of the British Standards Laboratory gives evidence of the excellent character of the work which is being done there. The organization of the laboratory embraces five departments: Physics, Engineering, Metallurgy, the Richmond Observatory, and the Eskdalemuir Observatory. Brief reports are given of the work accomplished during 1909 by each department, and of their plans for 1910. An interesting feature is the steady development of international coöperation with the Bureau of Standards and the Geophysical Laboratory at Washington, with the German Reichsanstalt, and other national laboratories.

H. A. B.

II. GEOLOGY AND MINERALOGY.

1. *United States Geological Survey*; GEORGE OTIS SMITH, Director.—Recent publications of the U. S. Geological Survey are noted in the following list (continued from xxix, pp. 363-365):

TOPOGRAPHIC ATLAS.—Forty-two sheets.

FOLIOS.—No. 170. Mercersburg-Chambersburg Folio, Pennsylvania; by GEORGE W. STOSE. Pp. 19, with 18 figures, one chart, and 3 colored maps.

No. 173. Laramie-Sherman Folio; by N. H. DARTON, ELIOT BLACKWELDER, and C. E. SIEBENTHAL. Pp. 17, with 7 colored maps and 11 figures.

BULLETINS.—No. 398. Geology and Oil Resources of the Coalinga District, California; by RALPH ARNOLD and ROBERT ANDERSON. With a Report on the Chemical and Physical Properties of the Oils; by IRVING C. ALLEN. Pp. 354, 52 plates, 9 figures.

No. 406. Preliminary Report on the McKittrick-Sunset Oil Region, Kern and San Luis Obispo Counties, California; by RALPH ARNOLD and HARRY R. JOHNSON. Pp. 225, 5 plates, 2 figures.

No. 407. Geology and Ore Deposits of the Bullfrog District, Nevada; by F. L. RANSOME, W. H. EMMONS, and G. H. GARREY. Pp. 130, 14 plates, 20 figures.

No. 415. Coal Fields of Northwestern Colorado and Northeastern Utah; by HOYT S. GALE. Pp. 265, 22 plates, 8 figures.

No. 417. Mineral Resources of the Nabesna-White River District, Alaska; by F. H. MOFFIT and ADOLPH KNOPE. With

A Section on the Quaternary ; by S. R. CAPPS. Pp. 64, 5 plates, 3 figures.

No. 419. Analysis of Rocks and Minerals from the Laboratory of the United States Geological Survey, 1880 to 1908 ; tabulated by F. W. CLARKE. Pp. xii, 323.

No. 420. Economic Geology of the Feldspar Deposits of the United States ; by EDSON S. BASTIN. Pp. 85, 4 plates.

No. 422. The Analysis of Silicate and Carbonate Rocks: A Revision of Bulletin 305 ; by W. F. HILLEBRAND. Pp. 239, 27 figures.

No. 428. The Purchase of Coal by the Government under Specifications, with Analyses of Coal delivered for the Fiscal Year 1908-9 ; by GEORGE S. POPE. Pp. 80, 8 tables.

No. 430. Advance Chapters from Contributions to Economic Geology—A. Gold and Silver ; by J. M. HILL, F. L. HESS, D. F. MACDONALD and J. T. PARDEE—B. Part I. Copper ; by L. C. GRATON, H. S. GALE, and G. W. STOSE. Pp. 66, 5 figures—C. Lead and zinc ; by L. J. PEPPERBERG—E. Iron and manganese ; by E. C. HARDER, J. L. RICH, A. C. SPENCER, and SIDNEY PAIGE. Pp. 56, 1 plate, 4 figures—G. Mineral Paints ; by J. C. STODDARD, A. C. CALLEN, F. T. AGTHE and J. L. DYNAN—I. Salines ; by C. L. BREGER and A. R. SCHULTZ.

WATER SUPPLY PAPERS.—No. 236. The Quality of Surface Waters in the United States. Part I.—Analyses of Waters east of the one hundredth meridian ; by R. B. DOLE. Pp. 123.

Nos. 241-249. Surface Water Supply of the United States, 1907-8. Prepared under the direction of M. O. LEIGHTON. No. 241. Part I. North Atlantic Coast ; by H. K. BARROWS and R. H. BOLSTER. Pp. 356, 6 plates. No. 243. Part III. Ohio River Basin ; by A. H. HORTON, M. R. HALL, and R. H. BOLSTER. Pp. 224, 4 plates, 1 figure. No. 244. Part IV. St. Lawrence River Basin ; by H. K. BARROWS, A. H. HORTON, and R. H. BOLSTER. Pp. 163, 7 plates, 1 figure. No. 245. Part V. Upper Mississippi River and Hudson Bay Basins ; by A. H. HORTON, E. F. CHANDLER, and R. H. BOLSTER. Pp. 133, 5 plates, 1 figure. No. 247. Part VII. Lower Mississippi Basin ; by W. B. FREEMAN, W. A. LAMB and R. H. BOLSTER. No. 248. Part VIII. Western Gulf of Mexico ; by W. B. FREEMAN, W. A. LAMB, and R. H. BOLSTER. Pp. 171, 4 plates, 1 figure. No. 249. Part IX. Colorado River Basin ; by W. B. FREEMAN and R. H. BOLSTER. Pp. 206, 10 plates.

2. *Illinois Geological Survey*. Bulletin No. 13, The Mississippi Valley between Savanna and Davenport ; by J. ERNEST CARMAN. Pp. xi, 85 ; 23 plates, 26 figures and map. University of Illinois, Urbana, 1909.—This is another of the excellent educational bulletins issued by the Illinois Survey. While the object of the bulletin is to give a detailed account of the stratigraphy, physiography and glacial geology of this part of the Mississippi Valley, it should attract readers beyond the state because of the clear way in which the accepted views regarding glaciation, and particularly eolian sand and loess, are discussed.

Bulletin No. 14, Year-Book for 1908; H. FOSTER BAIN, Director. Pp. viii, 386, 5 plates, 5 figures.—The Illinois Survey continues to do a large amount of effective work as indicated by its publications and its plans for the future. Its organization, including the geological section, topographic section, and drainage section, is admirably designed to meet the particular needs of the state. Furthermore, desire to prevent duplication of work is indicated by the fact that the Survey is in active coöperation with the United States Geological Survey, United States Department of Agriculture, the State Water Survey, the Internal Improvement Commission, the State Conservation Commission, as well as with the University of Illinois and Augustana College. The request for an increase in the annual appropriation from \$25,000 to \$35,000 is certainly justified by the work accomplished.

The important classes of work undertaken by the Geological Section are: The study of drill records in connection with stratigraphic work under the direction of Weller, Savage and others, with a view to ultimately making a structural map of the state; a study of the coal fields preliminary to detailed mapping; investigation of Portland cement material including clays and shales. The fact that Illinois ranks second in coal production explains the need for stratigraphic and structural work; and the large importation of Portland cement justifies care in investigating local resources.

The Topographic Section in coöperation with the Geological Survey has mapped 4366 square miles, leaving, however, a large part of the state, 47,847 square miles, still to be covered. The Drainage Section is devoting its attention chiefly to an examination of "bottom lands" because at the present time 90 per cent of these lands are unprotected from floods, and it is estimated that \$100,000,000 would be added to farm values of the state if these lands could be reclaimed. Seven special reports are included in this bulletin.

H. E. G.

3. *Northern Territory of South Australia: North and Eastern Coasts. Report of Geological Reconnaissance from Van Dieman Gulf to the McArthur River, etc., made by the Government Geologist in 1907*; by H. Y. L. BROWN. Government Geologist. Pp. 12, with map. Adelaide, 1909.—Continuing the exploration carried on during 1905, Mr. Brown explored in a preliminary way the region along the North Australian Coast line from Van Dieman Gulf to Melville Bay. This region is practically unknown scientifically, a fact which justifies the inclusion of notes regarding the condition of the natives, the character of the coast line, the fauna, flora and climate of the region as well as the geology. In this reconnaissance trip no detailed geological work was done, but the presence of the pre-Cambrian, Cambrian, Permo-Carboniferous, Cretaceous, and Tertiary sediments are proven, as well as the presence of basalt, and certain other types of volcanic rock. Valuable gold deposits were found, the presence of tin and bauxite in commercial quantities was demonstrated, and the boring for coal at Mallison Island, Arnheim Bay, and Boroloola is recommended.

It is to be hoped that the reconnaissance survey is to be followed by detailed work, which will result in a fuller knowledge of this interesting and unknown region.

H. E. G.

4. *Corrasion by Gravity Streams with Applications of the Ice Flood Hypothesis*; by E. C. ANDREWS, Department of Mines, Sydney. Reprinted from Journal and Proc. of the Royal Society of N. S. Wales, vol. xliii, pp. 204-330, with 11 figs., 3 appendices and a bibliography.—This is an important paper which should be called to the attention of American geologists interested in surface processes. The author is best known by his previous paper on the Ice Flood Hypothesis,* in which he maintained the excessive erosive power of glaciers during their period of maximum development, or flood, as compared with their weak erosive effects during stages of recession. In the present paper he takes up the subject of stream erosion more broadly as the action of the gravity stream, irrespective of the fluid or solid which composes it, and discusses the laws of its movement. To sum up the results of his conclusions it may be noted,—that U-shaped valleys and cirques are forms characteristic of maximum or flood erosion and are not forms solely dependent upon ice as a medium. Even where the stream of ice or water covers a region broadly it will erode unequally. During the flood stages it shows an excessive effect upon the bottoms of the principal channels in contrast to its flood plain and increases the relief of the region. During drought stages aggradation tends to take place within these overdeepened and oversteepened channel walls. Through the formulation of these principles the author discusses changes in the character of glacial erosion between the ice age and the present, and draws distinctions between those features which are essentially peculiar to ice as a medium. Applications of his discussions resulting in some new conclusions are made, among other regions, to the California Sierras, the Finger Lake region, the St. Lawrence and the Hudson Rivers.

As the original paper may be difficult of access to many who may wish to quote some of Andrews' statements, the following conclusions are quoted, the bearing of which may be better appreciated in the light of the preceding statements:

"A. *Inductive Studies*.—(1) Cirques, hanging valleys, rock basins, faceted spurs (or spurless walls), smoothed cols, "steps," and "treads" occur in all recently glaciated regions. (2) In proportion to the intensity of the recent glaciation so are these peculiar land profiles pronounced in number, size, and appearance. (3) In localities not glaciated recently such peculiar land profiles are absent. (4) All these forms are matched in miniature along any channel determined by thunderstorm waters. (5) Along the beds of even large stream channels similar forms occur to those just enumerated. (6) The forms in all these cases are similarly situated with respect to their enveloping channels. (7) The forms in each case are adjusted to the size of the various stream

* Jour. Geol., vol. xiv, pp. 22-54, 1906.

volumes (whether ice or water) known to have been associated with them.

"B. *Inductive Studies*.—(1) All streams in nature are due primarily to pressure and weight. (2) The path of any stream particle tends to the parabolic form. (3) All must seek the lines of least resistance, and inasmuch as a vertical force (gravity) determines the flow, the lines of least resistance will be the lines of quickest descent for streams. (4) All streams therefore tend to follow the thalwegs of each other as opportunity arises. (5) Increased pressure as weight implies the increased mobility or velocity of a stream. (6) Increased velocity implies corrasive action rising in a high geometrical ratio. (7) From the foregoing the profiles of all stream channels formed individually by one stream type only should therefore be similar in general appearance. (8) The forms developed by the general stream have been worked out by means of these principles. (9) But the forms deduced for the general stream are matched in nature in the case of the ordinary water stream (which has been definitely observed moreover to have formed its own channel profiles). (10) Therefore any group of such similarly shaped, similarly situated, and similarly associated profiles as those deduced for the general stream can be satisfactorily explained by stream action. (11) But such groups of forms occur in regions of recent glaciation. (12) They can be satisfactorily explained, therefore, by stream action. (13) Moreover, glaciers themselves are streams. (14) Glaciers in recent times occupied the same general relations (as to size, surface, and so on) to cirques, lake basins, over-deepened valleys, and other associated forms which the general stream type has been deduced to occupy with regard to its own channel forms. (15) With the exception of a glacier no other stream in these glaciated regions is known which had the power to fashion the typical cirque, rock basin and spur "facet." (16) Glaciers therefore, in all probability, formed the typical cirques, the fiord and Alpine basins, the spurless chasms of Alpine regions, as also the hanging valleys and the "steps" and "treads" in Alpine valleys.

"C. *Apparent Lack of Ice Corrasion as Evidenced by a Study of Present Glaciers*.—The channel form is adjusted to the strength of the stream. Upon a reduction of stream volume a readjustment of the channel grade is set up, and the stream appears most inert at the locations of the maximum energy exerted by the larger stream. This is the case with present-day glaciers. The recent ice-floods formed cirques, rock basins, and other forms adjusted to their own size and strength, while the deglaciated valleys of to-day evidence the very recent retreat of the last ice flood. The channel grade, therefore, must now be readjusted. This being so, morainic material must fall out along the old cutting curves, and the ice generally must be most inert at spots like fiords and lake basins. This explains the apparent anomaly otherwise of the association of inert and banded glaciers with cirques and rock basins, and the occupation of old ice-cutting curves by moraines."

H. E. G. J. B.

5. *Die Antike Tierwelt*; by OTTO KELLER. Erster Band. Säugetiere I. Pp. xii, 434, with 145 text-figures and 3 plates. Leipzig, 1909 (Wm. Engelmann).—This very interesting volume describes, with many illustrations, the various mammals known to the ancients, not only the domesticated animals but wild and some mythical forms as well: more than 200 species and varieties all told, such as are depicted in statuary, bas reliefs, mural paintings, coins and vases, or described by the writers of old.

The volume opens with a brief résumé of the zoölogical system of Aristotle, the remainder of the book being devoted to the Mammalia, of which the principal forms described are the apes, the lion and other felines, the dog, hyena, bear, many rodents, among which are mentioned the conies (*Hyrax*), which are nearer the proboscideans among the ungulates than the hares which they superficially resemble. Horses, deer, giraffe, antelope, and their kind were well known to the ancients, and the elephants, including the hairy mammoth, which is depicted in prehistoric drawings upon cavern walls of France. Rhinoceros, swine, seals, and an amazing picture of a docile unicorn from the mediæval "Physiologus" close the volume. There are three plates of coins and medals bearing animal subjects.

The book, with its excellent illustrations and clear type, is of great interest and value to the natural historian as well as to the general reader.

R. S. L.

6. *The Orders of Mammals*; by WILLIAM K. GREGORY. Bulletin of the American Museum of Natural History, Vol. xxvii, Feb. 1910, pp. 1-525, and 32 text-figures.—Part I of this important memoir contains a history of the ordinal classification of mammals, while Part II deals with the genetic relations of the mammalian orders, a discussion of the origin of the Mammalia, and the problem of the auditory ossicles. Dr. Gregory's position in the American Museum which calls for so much literary as well as scientific research, together with close association with Professor Osborn and Dr. W. D. Matthew, have aided in fitting him peculiarly for the preparation of such a work. The author's thoroughness may readily be imagined by his devoting some time to a preliminary study of Descartes and the principles of inductive philosophy in order that his phylogenetic speculation be not rendered migratory by faulty reasoning.

This thoroughness is the keynote of the whole endeavor and has resulted in so valuable a work that a teacher of paleontology as well as one who deals with living mammals will find it a mine of information above price. It is written in the author's clear and very delightful style, while the typography is fully up to the high standard of the Museum's other publications.

R. S. L.

7. *Analyse der Silikat- und Karbonatgesteine*; von W. F. HILLEBRAND. 8vo, pp. 258. Leipzig 1910 (W. Engelmann).—This is essentially a translation into German, by E. WILKE-DÖRFURT, of Bulletin No. 305 of the U. S. Geological Survey (1907) by the same author.* At the same time, however, con-

* A revised edition has recently appeared as Bulletin 422, see p. 84.

siderable alterations and additions to the text of the original volume have been made by the author, which embody the results of more recent researches on methods of analytical work. They relate chiefly to the preparation of samples for analysis and to the estimation of water and the oxides of iron.

The writer in his preface to the German edition pays a graceful tribute to the German masters, especially Bunsen, under whom he studied, and this volume will be evidence to the chemists of that nationality that the seed sowed at that time has brought a fruitful harvest. There is no one who has greater skill, or has had a wider experience, in silicate analysis than the author, or who has done more to bring the analyses of rocks to a high standard, and it is well that his views and methods should have as wide an extension as possible. L. V. P.

8. *Manual of the Chemical Analysis of Rocks*; by H. S. WASHINGTON. Second edition, Revised and Enlarged. 8vo, pp. 200. New York, 1910 (Wiley & Sons).—This is a new edition of Washington's useful and practical treatise on rock analysis. New methods and modes of procedure, which have been tested by the author, have been introduced and numerous changes have been made in the text where more detail appeared to be needed. The analysis of carbonate rocks, as a special subject, has not been treated, as the latest work of Dr. Hillebrand, recently noticed in this Journal, covers this, and they are of minor importance to the petrographer.

The complete and accurate analysis of silicate rocks is one of the most intricate and difficult tasks the analytical chemist is called upon to perform, but by the aid of this work, in which every detail of operation is completely stated, even one of limited experience in this field may attain excellent results if he carefully follows its directions. It may be confidently recommended to chemists and petrographers, and should find a place in every chemical library. L. V. P.

9. *Handbuch der Mineralogie*; von DR. CARL HINTZE. Erster Band. Dreizehnte Lieferung. Pp. 1921–2080. Leipzig, 1910 (Veit & Comp.).—The successive parts of Hintze's monumental work on Mineralogy do not appear at very frequent intervals, but are none the less welcome on that account. This is the twenty-fifth section of the entire work and the thirteenth of the first volume; it is devoted to the oxides and chiefly to the species of the diaspore-goethite group.

10. *Crystallography: An Elementary Manual for the Laboratory*; by M. EDWARD WADSWORTH. Pp. xvi (20), 299, with 612 figures, and 25 plates. Philadelphia (John Joseph McVey), 1909.—This new Crystallography is based on the lectures delivered by the author at Harvard in 1873 and subsequently developed by him in University work elsewhere. Being prepared for those studying the subject in a general way only, the mathematical side is omitted entirely, and the discussion is limited to simple and readable descriptions of the different systems and the forms

peculiar to them, with a statement of the different types of symbols in use. The work differs from most books of similar scope in that the triclinic system is introduced first, a method which the author has found to give the best results with his pupils. The figures are numerous and are all presented in a series of twenty-five plates printed on thin paper and placed at the end of the volume.

11. *Brief Notices of some recently described Minerals.*—ANOPHORITE is an alkaline amphibole described by W. Freudenberg as occurring in the shonkinite of Katzenbuckel, Baden. It has the pleochroism of Brögger's cataphorite, but differs in chemical composition and in optical orientation; specific gravity, 3.166. Analysis gave:

SiO ₂	TiO ₂	Al ₂ O ₃	Fe ₂ O ₃	FeO	MnO	MgO	CaO	Na ₂ O	K ₂ O	H ₂ O	
49.79	5.37	1.98	7.54	9.18	0.36	11.59	3.16	7.92	1.85	1.52	
											= 100.26

—Ref. in *Jahrb. Min.*, i, 34, 1910.

BITYITE is a hydrated silicate of calcium and aluminium described by A. Lacroix from the pegmatite veins of Mt. Bity, Maharitra, Madagascar. It occurs in minute hexagonal (pseudo-hexagonal) plates of a yellowish-white color; hardness, 5.5; specific gravity, 3.05. An analysis by Pisani gave:

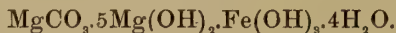
SiO ₂	Al ₂ O ₃	CaO	BeO	MgO	Li ₂ O	Na ₂ O	K ₂ O	H ₂ O	
31.95	41.75	14.30	2.27	0.13	2.73	0.40	0.16	6.50	= 100.19

—*Bull. Soc. Min.*, xxxi, 241, 1908.

BRUGNATELLITE is a hydrate and carbonate of ferric iron and magnesium, described by E. Artini, from Val Malenco, where it occurs in a serpentized peridotite. It forms lamellar aggregates of micaceous aspect, easy cleavage, pearly luster and flesh-red color. An analysis gave:

CO ₂	Fe ₂ O ₃	MgO	MnO	H ₂ O	insol.	
7.78	13.20	42.79	1.80	33.77	1.03	= 100.37

From this the formula is calculated:



Named after Professor L. Brugnatelli of Pavia.—*Rivista Min. Ital.*, xxxvii, 119, 1909.

HALLERITE is a silver-white mica with pearly luster described by Ph. Barbier, from the pegmatite of Mesvres, Autunois. It is near paragonite, yielding 7.63 p.c. Na₂O and 1.26 Li₂O. Named after Professor Haller of Paris.—*C. R.*, cxlvi, 1220, 1908.

JOAQUINITE is a rare titano-silicate of calcium and iron described by G. D. Louderback in a recent pamphlet which gives an exhaustive account of the remarkable barium titano-silicate benitoite. It occurs in small, honey-yellow or light brown crystals, enclosed in both natrolite and neptunite; the crystals are imperfect in form, but are referred with probability to the orthorhombic sys-

tem. Its hardness is 5·5–6, specific gravity, 3·85–3·9, and refractive index high, greater than 1·73. Only qualitative tests have thus far been made, but it is hoped that material for a complete analysis may be obtained.—*Bull. Geol. Univ. California*, v, p. 331.

PLANCHEITE is a hydrated copper silicate described by Lacroix from Mindouli, French Congo. It occurs in fibrous masses of a blue color associated with diopside; specific gravity, 3·36. An analysis by Pisani gave:

SiO₂ 37·16 CuO 59·20 FeO *tr.* H₂O 4·50 = 100·86.

Named after M. Planché.—*Bull. Soc. Min.*, xxxi, 250, 1908.

RISÖRITE is a niobate of the yttrium and cerium metals with other elements; it is described by O. Hauser from the pegmatite of Risör in southern Norway. It has a brown color, and is optically isotropic, probably from alteration; hardness, 5·5; specific gravity, 4·179; after ignition, 4·678. It is not far from fergusonite, but contains uranium in very small amount only.—*Ref. in Jahrb. Min.*, i, 37, 1910.

ROSASITE is a carbonate of copper and zinc, described by D. Lovisato from the Rosas mine, Suleis, Sardinia. It occurs in mammillary masses with fibrous structure and green to sky-blue color; hardness, 4·5, specific gravity, 4·07. Analysis gave:

CO ₂	CuO	ZnO	PbO	H ₂ O
30·44	36·34	33·57	<i>tr.</i>	0·21 = 100·56

—*Rend. Acc. Linc.*, xvii (2), 723, 1908.

VASHEGYITE is a basic aluminium phosphate described by Zimanyi, from the iron mines of Vashegy, Hungary. It occurs in dense white masses resembling meerschaum and immediately associated with variscite; hardness, 2·5. An analysis by Loczka gave:

P ₂ O ₅	Al ₂ O ₃	Fe ₂ O ₃	H ₂ O	K ₂ O	Na ₂ O	CO ₂	insol.
31·32	28·33	1·19	38·97	0·16	0·05	0·12	0·24 = 100·38

The calculated formula is 4Al₂O₃·3P₂O₅·30H₂O.—*Zeitschr. Kryst.*, xlvii, 53, 1909.

SAMSONITE is a sulphantimonite of silver and manganese from the Samson vein of the St. Andreasberg silver mines in the Harz; it is described by Werner and Fraatz. It occurs in monoclinic crystals, the color is red by transmitted light and it somewhat resembles miargyrite. An analysis, after deducting unessential constituents, gave:

S 20·45 Sb 26·33 Ag 45·95 Mn 5·86 = 98·59

This leads to the formula 2Ag₂S·MnS·Sb₂S₃.—*Centralblatt Min.*, p. 331, 1910.

12. *Les Cristallisations des Grottes de Belgique*; par W. PRINZ. Pp. 90, with 143 figures. Brussels, 1908.—The stalactitic formations in limestone caverns have often been described, but never

before with the fullness and care devoted to them in the present work. The author has had the opportunity to study the numerous caves in Belgium which afford stalactites and stalagmites of very great variety. Many of these are distinctly crystallized and show different rhombohedrons and scalenohedrons which can be definitely determined. In addition to the distinctly crystallized forms are many others of much interest and variety.

13. *Minéralogie de la France et de ses Colonies*; by A. LACROIX. Tome Troisième, 2^e Partie. Pp. 401-815. Paris (Librairie Polytechnique, Ch. Béranger, Editeur), 1909.—The earlier parts of this admirable Mineralogy of France and the French Colonies have been repeatedly noticed in this Journal. The present part completes Volume III and thus the entire work. It is devoted for the most part to the carbonates, and the species calcite, aragonite, and cerussite are discussed with admirable fullness, the text being accompanied by numerous illustrations. The author is to be congratulated on having brought to completion a work of such magnitude and importance.

III. NATURAL HISTORY.

1. *Fungous Diseases of Plants with Chapters on Physiology, Culture Methods and Technique*; by BENJAMIN MINGE DUGGAR, Pp. xii, 508, 240 figures. Boston and New York (Ginn and Company), 1909.—The writer was recently informed by an experienced mycologist of Europe that the United States led the world in the study of plant diseases, especially as regards their treatment. It is certainly true that since the establishment of the experiment stations in this country the study of fungous diseases has occupied a very prominent part in the work of the various station botanists. Until recently, however, we have had no text-book from an American author upon this very important branch of botany, though the subject is now taught either specifically or in a general way in most of our colleges.

Professor Duggar of Cornell University has the honor of giving us this first text-book, the title of which is quoted above. While the book is apparently designed primarily as a text- or reference-book for college use, it is of value to anyone wishing a general up-to-date knowledge of the subject. It is divided into three parts, of which the first and second treat of culture methods, technique and physiological relations of the fungi. The greater part of the volume, however, is occupied by the third part, with descriptions of the most important fungous diseases of our economic plants. These fungi are taken up according to their systematic relationships, and under each is given its more important literature, its general life history, and the methods employed in controlling it.

The book is well illustrated with halftones and drawings. The text is carefully written and the mechanical execution is above

the average. On the whole, it is a work that fills a decided need, and the subject is presented in a manner very creditable to the author.

G. P. C.

2. *The British Freshwater Rhizopoda and Heliozoa*; by the late JAMES CASH, assisted by JOHN HOPKINSON. Volume II, Rhizopoda, Part II. Pp. xviii, 166, with 16 plates, of which 10 are colored. London (Ray Society). 1909.—This is the second of the three volumes of the Monograph on these widely distributed groups of Protozoa, the first volume, including the Amœbina and a part of the Arcellida, having been published in 1905, while the third volume is promised for an early date. Of the Conchulina, or case-bearing Rhizopods, the present volume describes some 80 species belonging to 14 genera, all of which are illustrated. As many of the species occur not only in Great Britain, but also in America and other parts of the world, the book will have a wide sphere of usefulness. For students of North American zoology it will form a valuable supplement to Leidy's superbly illustrated Monograph on the North American Freshwater Rhizopods, published some thirty years ago by the U. S. Geological Survey of the Territories.

W. R. C.

3. *Guide to the Genera and Classification of the North American Orthoptera*; by SAMUEL HUBBARD SCUDDER. Pp. 89. Cambridge, 1897 (Edward W. Wheeler).—A key for the use of entomologists, with bibliographical notes to date of publication.

W. R. C.

4. *Nature Study by Grades: A Text-book for Lower Grammar Grades*; by HORACE H. CUMMINGS. Pp. viii, 208. New York, 1910 (American Book Company).—This attractive little book consists of topics for two years' work in nature study, adapted to children of ten or twelve years of age. The subject is divided into 120 lessons, each of which furnishes suggestions which should encourage the pupil to observe the familiar phenomena of nature and the properties of the common things about him.

W. R. C.

5. *The Body and its Defences*; by FRANCES GULICK JEWETT. Pp. viii, 342, illustrated. Boston and New York, 1910 (Ginn and Company).—Essentially a practical discussion in simple language of the natural conditions which prevail in the human body, to the end that the reader may clearly understand the baneful effects of unhygienic living. The penalties which may thus result from ignorance or disregard of the proper care of the bodily mechanism are vividly illustrated, and practical advice is given as to how, by coöperation with the natural defences of the body, such penalties may be largely avoided.

This book carries a message that should impress the reader, be he schoolboy or adult, with a higher sense of his responsibility for the welfare of his own body.

W. R. C.

6. *A Synonymic Catalogue of Orthoptera*; by W. F. KIRBY. Vol. III, Orthoptera Saltatoria. Part II (Locustidæ vel Acrididæ). Pp. vii, 674. London, 1910 (printed by order of the

Trustees of the British Museum: sold by Longmans & Co. and others).—This third volume of the catalogue of the Orthoptera in the British Museum completes the work undertaken by Mr. Kirby a number of years since. It is devoted to the Locustidæ or Acridiidae, that is, the short-horned grasshoppers or migratory locusts. Volume I of the catalogue was issued in 1904, Volume II in 1906. An Appendix and Catalogue bringing it up to date was at one time contemplated but found to be impracticable.

7. *Catalogue of British Hymenoptera of the Family Chalcididæ*; by CLAUDE MORLEY. Pp. 28. London, 1910 (printed by order of the Trustees of the British Museum), sold by Longmans & Co., and others, 1910.—A catalogue has now been issued of the difficult and little-known group of the Chalcididæ, about which practically nothing has been published since the time of Francis Walker. With this work the series of catalogues of British Hymenoptera is now complete.

8. *Catalogue of the Lepidoptera Phalaenæ in the British Museum. Volume IX. Catalogue of the Noctuidæ*; by Sir GEORGE F. HAMPSON. Pp. xv, 552, with 11 plates and 247 figures. London, 1910.—This ninth volume of the Catalogue of Moths represented in the British Museum includes the third and final portion of the large Noctuid sub-family Acronyctinæ. It contains 725 species belonging to 185 genera.

9. *The Museum of the Brooklyn Institute of Arts and Sciences*.—The following has recently appeared: Science Bulletin, Vol. I, No. 17. Additions to the Carabidæ of North America with Notes on Species already known; by CHARLES SCHAEFFER. Pp. 391–405. May, 1910.

IV. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *The Carnegie Foundation for the Advancement of Teaching*. Bulletin No. 4. Medical Education in the United States and Canada: A Report to the Carnegie Foundation for the Advancement of Teaching; by ABRAHAM FLEXNER; with an Introduction by HENRY S. PRITCHETT. Pp. xvii, 346. New York, 1910.—The management of the Carnegie Foundation has taken a broad view of the work which has devolved upon it. What it is doing in the general line of University and College work is well known, but in this bulletin we have the first of a series of papers devoted to the Professional Schools. This has been prepared by Mr. Abraham Flexner; he deals with the whole subject of medical education, treating it not only historically but taking up what is regarded as the proper basis of a medical education as compared with that actually existing, and dealing also with other topics, such as laboratories, the relations of the hospital and the medical school, etc. The latter half of the work gives the data collected in regard to the individual schools in the United States and Canada, arranged alphabetically. The standard called for is cer-

tainly high—much higher than that to which the majority of medical institutions now attain—but not too high to insure the best possible training of medical men for the sake of the public to whom they are to minister.

2. *Carnegie Institution of Washington*.—Recent publications of the Carnegie Institution are noted in the following list (continued from p. 368, v. xxix).

No. 85 (Delaware). Index of Economic Material in Documents of the States of the United States. Delaware 1789–1904. Prepared for the Department of Economics and Sociology of the Carnegie Institution of Washington; by ADELAIDE R. HASSE. Pp. 137, 4to.

No. 87, Volume II. The California Earthquake of April 18, 1906. Report of the State Earthquake Investigation Commission. In two volumes and Atlas. Volume II: The Mechanics of the Earthquake; by HARRY FIELDING REID. Pp. viii, 192, 4to, with 2 plates and 62 figures.

No. 96 (Part 2). Condensation of Vapor as induced by Nuclei and Ions. Fourth Report; by CARL BARUS. Pp. viii, 84.

No. 105. Factor Table for the first Ten Millions, containing the Smallest Factor of Every Number not divisible by 2, 3, 5, or 7 between the limits 0 and 10017000; by DERRICK NORMAN LEHMER. Pp. 476, folio.

No. 115. Preliminary General Catalogue of 6188 Stars for the Epoch 1900, including those visible to the naked eye, and other well-determined stars; prepared at the Dudley Observatory, Albany, New York, by LEWIS BOSS. Pp. xxxvii, 345, 4to, with 3 appendices.

No. 123. Respiration Calorimeters for Studying the Respiratory Exchange and Energy Transformations of Man; by FRANCIS G. BENEDICT and THORNE M. CARPENTER. Pp. vi, 102, with 32 figures.

No. 125. Determination of Atomic Weights. Further Investigation concerning the Atomic Weights of Silver, Lithium, and Chlorine; by THEODORE W. RICHARDS and HOBART HURD WILLARD. The Harvard Determinations of Atomic Weights between 1870 and 1910; by THEODORE W. RICHARDS. Methods Used in Precise Chemical Investigation; by THEODORE W. RICHARDS. Pp. iv, 113.

3. *Publications of the Allegheny Observatory of the University of Pittsburgh*.—The following paper has recently appeared: Volume I, No. 22. The Spectroscopic Binary β Aurigæ; by ROBERT H. BAKER. Pp. 163–190, with 14 tables.

OBITUARY.

WILLIAM PHIPPS BLAKE, Professor of Geology, emeritus, in the University of Arizona, died on May 22d at Berkeley, California, whither he had gone to take part in the fiftieth anniversary of the University of California. He was born in New

York on June 1st, 1826, and was educated at the Scientific School of Yale University in 1852, being one of three to receive the degree of Ph.B. in the first class of the institution; his colleagues were Professors Brush and Brewer of New Haven.

The career of Professor Blake was interesting and varied, especially in the exploration of wild regions which have now become comparatively well-known. From 1854 to 1856 he acted as mineralogist and geologist in the explorations and surveys for the proposed Pacific railroad, reaching California by the southern route only a few years after the discovery of gold, when the excitement was still at its height. At that time he first called attention to the great Colorado desert with its extensive area below the sea-level. He also carried on mining explorations in North Carolina and Georgia in 1860, and from 1861 to 1863, with Mr. Raphael Pumpelly, was employed by the Japanese Government in the examination of the mineral resources of that country. Before returning from Japan he visited China and also Alaska, where he explored the Stickeen River and its glaciers. This was shortly before Alaska was purchased by the United States Government in 1867. In 1863 he visited California again, and was engaged as mining expert in connection with the Comstock lode. His varied work in similar lines was further extended by a trip to Santo Domingo in 1871. In another direction also he served his country and science well and had wide experience of a different kind, being Commissioner to the World's Fair of 1853, as also at the subsequent World's Fairs of Vienna in 1873, Philadelphia in 1876—the Centennial Exposition—and Paris in 1878. In 1864 he was Professor for a time in the College of California, later the University of California, and thirty years afterwards he became Professor of Geology and Director of the School of Mines of the University of Arizona; he was also territorial geologist of Arizona for many years. In 1895 he became Professor emeritus; his death came suddenly from pneumonia when he lacked but a few days of completing his 84th year.

Dr. GEORGE FREDERICK BARKER, Professor of Chemistry, emeritus, at the University of Pennsylvania and for many years an associate editor of this Journal, died on May 24 at the age of seventy-five years. A notice is deferred till a later number.

Professor FRANKLIN C. ROBINSON, the chemist, long connected with Bowdoin College, died on May 25 at the age of fifty-eight years.

AUGUST VON MICKWITZ, the well-known City Engineer and Paleontologist of Reval, Russia, died on April 20th last at the age of 61 years. His best known work in paleontology treats of the Upper Cambrian Obolidae and Lingulidae of western Russia.

ROBERT H. GORDON, long interested in the geology of western Maryland, and the donor of extensive collections of the finely preserved Lower Devonian fossils of this region to the U. S. National Museum and to Yale University, died on May 10th last at the age of 58 years.

THE

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[FOURTH SERIES.]

ART. VII.—*On an Artificial Lava-Flow and its Spherulitic Crystallization*; by L. V. PIRSSON. (With Plate I.)

THE material which forms the basis of the following article, was obtained a number of years ago by the late Prof. Chas. E. Beecher, of Yale University, at Kane, an industrial town with glass-works, in McKean county, Penn., and presented to the writer. It appears that one of the furnaces in the glass-works accidentally broke, allowing the molten glass to escape; it flowed into the pit below and cooled there. When cold the mass of glass was blasted out and the broken material piled on one side. It was from this broken material that the specimens were obtained. The furnace is stated to have been 60 feet long by 25 feet wide, and the molten glass in it at the time to have been from 4 to 5 feet deep. This would have made about 6000 cubic feet of glass, or say 700,000 pounds, an amount which formed a flow of no mean size, when viewed from the experimental standpoint. During the flow and while cooling it partially crystallized, assuming features which it is the object of this paper to present. An accident of this kind to a glass furnace by which a flow of molten glass was produced, which partly crystallized, has been described by the late Professor Fouqué.* In this case portions of the glass were filled with milky white nodules with a greenish cast of color, which were in places the size of a nut. These nodules were spherulites which Fouqué proved to consist of radially fibrous prisms of wollastonite. Thanks to the kindness of Professor A. Lacroix of the Musée d'histoire naturelle in Paris the writer has been able to examine some of the glass described by Fouqué and to confirm his conclusions. The present material, while resembling it in some respects, differs in several important particulars, as will be presently shown.

*Compt. Rendus, cix, Jan. 1, 1889.

Morozewicz* has also described crystallizations resulting from the outflowing of glass from industrial furnaces; in this case large single crystals of wollastonite were formed. He mentions also rounded aggregates of fibrous diopside, but does not describe them definitely as of spherulitic structure.

Spherulites.—The most important kind of crystallization shown by the Kane glass-flow is in the formation of spherulites. The glass itself is an ordinary green bottle glass, pale greenish where thin and a clear, sea-green when a couple of inches thick or more. This is more or less filled with white spherical bodies which vary in size from that of very fine shot up to those which are nearly the size of an egg. These, and especially the largest ones, may be readily broken out of the glass, either as single spheroids, or as grouped or botryoidal masses. When extracted they have a smooth, thin, outer shell of glass which covers them like a skin. These solid bodies when broken open are white, with a pale greenish tinge, and are seen to possess a fibrous radiated structure. The fibers are extremely fine and thread-like, giving to the surface the luster of floss silk. This is true even in the largest. In some the cross section of the broken spherule, as it lies in the glass, appears radial but uniform, while in others changes in the conditions of crystallization, as the fibers grew outwardly from the center, have produced a series of concentric rings, such as are sometimes observed in the smaller spherulites in rhyolite. As many as ten of these rings, of almost perfectly circular form and of similar width, have been observed in one spherulite, and, thus mottling the silky sheen of the surface of the section of the divided spherulite, they have a moiré, or concentric, watered-silk appearance, and add greatly to its beauty. The structure, or consistency, of the spherulites varies greatly; some are so compact that they are composed almost wholly of crystalline material, while in others the thread-like fibers are relatively widely separated and the whole spherulite is saturated with the greenish glass. Thus, while the first form very solid white objects, the latter appear almost like misty or cloudy forms in the green matrix surrounding them, and the conchoidal fracture passes through the glass without reference to them nor can they of course be broken out and separated from it.

In another portion of the flow which formed a sheet about two inches thick the spherulites have a somewhat different character. Here they appear to be composed, not of tenuous fibers, but of distinct, rather thick, blades, 0.5–1.0^{mm} broad by 4^{mm} long, as may be seen by reference to figs. B and C in Plate I which represents them in very nearly natural size.

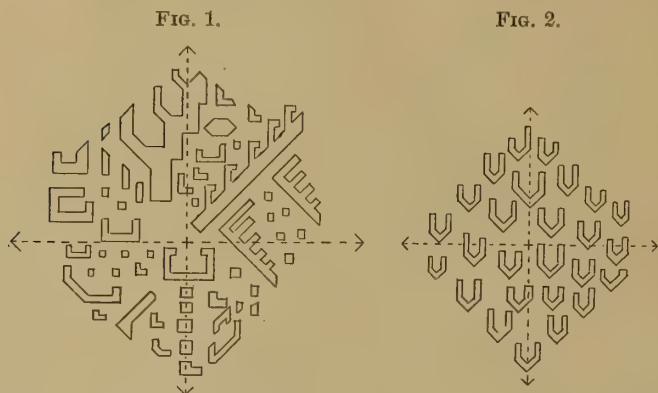
* Min. Petr. Mitt., xviii, p. 124, 1898.

They average about 7-8^{mm} in diameter. In addition to the regular spherulites various modifications of them exist in this place, as may be seen by reference to the plate. Some are composed of only a few blades, or even only two or three, radiating from a center in a star-like group, but with blades the same size and length as those of the more complete spherulites. The beauty of these white radiate and stellate crystallizations suspended in the clear sea-green glass is very striking, and the fact that they are thus suspended and did not fall to the bottom shows that at the time of their formation the molten glass was in too viscous a condition to permit of such movement, a fact whose bearing upon the question of their origin will be treated later. The bottom of this sheet of glass is composed of a layer of spherulites about 3-4^{mm} in thickness. Looking at the bottom surface itself it appears flat and smooth but so thickly covered with the radiate crystallizations of these spherulites, seen in half section, that they nearly everywhere coalesce, or are contiguous. The appearance recalls surfaces covered with radiate zeolites or frosted window-panes in winter. The upper surface of this layer presents a somewhat mossy appearance as the rounded, bladed, surfaces of the spherulites project into the glass. It is seen on the right hand side of figs. B and C in the plate. The white cloudy area near the top of the piece in fig. C is due to the internal reflection of light in the glass and nearly conceals a very fine spherulite. The blades composing these spherulites are small at the center where they unite and grow larger gradually as they extend into the glass. They are four sided with apparent right angles and are terminated by an oblique plane, but the crystallization is rough and imperfect. Close inspection of the photograph will show these details.

Mineral Composition.—The study of the mineral composing these spherulites in thin sections and in powdered grains under the microscope proves that it is artificial diopside. This is seen from the following properties: inclined extinction, c on c measured to a maximum of 39° ; sections having parallel extinction show the exit of an optic axis on the edge of the field and that the plane of the optic axes lies in the clinopinacoid parallel to the length of the prism; by repeatedly measuring the width of the nearly square prisms as they lie in the glass their thickness is also obtained, and the birefringent color yielded by those having the maximum angle of extinction indicates that the maximum birefringence is about 0.03. The cross section of the prisms shows them to be nearly square, but they are too minute to show the cleavage parallel to the prismatic sides; the extinction bisects the angle. These are the properties of diopside and the physical determination was confirmed

by qualitative chemical tests on material extracted from the glass which proved, in addition to the silica, the presence of traces of iron and alumina and abundant lime and magnesia. It is evident that a dolomite limestone was used in the making of the glass.

Microstructure of Crystals.—When studied under the microscope in powdered form it is found that the crystal blades, illustrated in the photographic plate, are very far from being the solid continuous crystals they appear. Close inspection of them with a simple lens, as they lie in the glass, proves them to have a parallel fibrous structure. The microscope



FIGS. 1, 2. Skeleton crystals of diopside.

shows them in length sections to consist of bundles of extremely slender rods or fibers. These are sometimes closely packed, sometimes separated by much more than their own diameters. They are surrounded by, or are cemented together, by the glass in which they lie. Sections across these fibrous bundles, or blades, prove that to a great degree they are not simple solid fibers, or rods, but are more or less hollow, or skeleton-like in form, and that groups of them have a similar crystallographic orientation. One of these is shown in the adjoining fig. 1. The directions of extinction in this are indicated by the broken arrow lines; these indicate the plane of symmetry in the compound or skeleton crystal and it is interesting that the directions of growth are along both pinacoidal and prismatic faces. Another type is shown in fig. 2; the growth here is along the clinopinacoid $b, 010$, and the prismatic faces; that along the orthopinacoid being wanting. A number of different patterns of growth were observed but they are sufficiently illustrated by these examples.

Chain Spherulites.—An interesting feature is the presence of chain spherulites along flowage lines, as illustrated in the photographic plate fig. A. The white lines are composed of layers of innumerable minute spherulites, while the darker layers between are of clear green glass free from crystalline products. Examination with a lens reveals the fact that almost without exception these lines are composed of a chain, or layer, of single spherulites. Generally they are so closely crowded that they coalesce to a considerable extent, less often they touch at the circumference, and in some places they appear quite regularly spaced but separated by areas of glass, generally not wider than their own diameter. Viewed with the lens from above, a layer appears like one of minute white pills sifted into the glass, innumerable in number and spread without order, here thickly clustered, there more thinly distributed. The average size of these spherulites is $0.5-0.6^{mm}$ and they do not vary much from it. Under the microscope in thin section they appear like the spherulites of feldspar seen in acid lavas, so much so that it is almost difficult to believe one is not dealing with a section of rhyolite. Although snow-white in the glass, and also as seen by the microscope with reflected light from the section, they appear of a light leather-brown color by transmitted light. With a low magnification the central part of the spherulite looks uniform and homogeneous, the fibrous character appears more evident as the outer boundary is approached, and the outermost zone is composed of distinct, branching, fibrous rays. With high magnification the central part is also resolved into masses of excessively fine, tenuous, matted fibers. At the center, where these fibers are cut perpendicularly, they appear as mere points.

When the structure of these bodies is revealed by the use of crossed nicols, it is seen that they are not formed uniformly of single fibers radiating from a common center, but rather of groups, or bundles, of fibers somewhat radially divergent, like brooms, or brushes; closely stellate groupings of which form the spherulites. Thus they repeat on a minute scale the examples shown in B and C of the plate and described in the preceding section. Like other spherulites they show a black cross, which is sometimes in one bundle, or brush, parallel with the planes of the nicols and sometimes, as the spherulite is revolved and a new brush comes into position, is somewhat inclined, proving that in each brush the majority of the minute fibers tend to have orientated positions and thus make a compound skeleton crystal. This is also like the larger ones described and figured in the preceding section.

The light leather-brown color of the sections of these spherulites is a curious feature. It is strongest in the central areas

where the fibers are finest and most closely packed; at the periphery, where they are coarser and more individualized, it is wanting. With a very high magnification of the center and parallel light from below, it disappears. With low-powered objectives it is present, whether the lower nicol is present or not. The spherulites of feldspars in acid volcanic lavas often show the same phenomenon of brown coloration, and so do the closely packed aggregates of minute scales of kaolin in feldspar. Since in all these cases the component mineral fibers, or scales, are white, that is to say colorless, this effect cannot be due to a pigment, but must be an optical phenomenon due to the absorption of light. An explanation of this may be somewhat as follows: Angular fibers or scales of a colorless mineral lying in all positions in a medium of lower refractive index may act as prisms to rays of light passing through them. The rays of white light would be then decomposed into their primary colors, and the violet rays more inclined than those of the red. On passing upward and striking inclined surfaces of new fibers, or scales, the light in the violet end of the spectrum, on account of its greater inclination than that towards the red end, would tend in greater measure to suffer total reflection and be absorbed, while the less inclined rays of the red and yellow would pass through and, illuminating the dark areas of total reflection, give the fibrous mass the brown tone. This explanation is based essentially on the same principle as that given by von Federov* for the pseudo-pleochroism which he observed in minerals containing thin parallel laminations. Only in this case there is no parallelism, the angular fibers lie in all directions, hence there is no apparent pleochroism and the mass appears of the same brown color in all positions and with, or without, polarized light.

It may be that in this lies the explanation of the brown and gray colors and pleochroic effects observed in spherulites in certain volcanic glasses by Cole,† but a search through the literature has not yielded to me any discussion of the frequent brown color of spherulites (or kaolin) though so commonly observed. Probably it is usually ascribed, if noticed, to some ferruginous pigment, to which in some cases it is undoubtedly due.

Some other features of interest which these spherulites show are as follows: In some, especially larger ones, hollow cavities appear; others have no cavities but a pronounced crack running through the center; often this crack passes along through several of them, and it is always rigorously parallel to the direction which the chain or line of spherulites makes (line of

* Min. Petr. Mitt., xiv, p. 569, 1895.

† Quar. Jour. Geol. Soc., xliv, p. 302, 1888.

flow). Where one has a cavity the ones immediately adjacent are apt to have the crack. In some places this crack has opened quite widely and an ellipsoidal or lenticular cavity is produced, bordered on either side by half spherulites extending into the glass. The bearing of these facts is discussed in a later place.

Another feature, quite similar to what is often seen in acid volcanic glasses, is the presence of cracks in the glass immediately surrounding the spherulites. These commonly start out from the edge of the spherulite, and especially from the place where two tend to intersect, and then curve, sometimes splitting and forming a Y. Usually after a short curve they stop, but quite often they continue in a long curve concentric to the outer surface of several adjacent spherulites and removed from it a small fraction of the total diameter of one of them (see fig. 3). It is owing to these concentric cracks surrounding them that the larger spherulites may be readily broken out of the glass and then appear with a thin, smooth skin, like varnish, coating them.

FIG. 3.



FIG. 3. Spherulites with cavities and cracks.

Stony Material.—In the material represented in the collection there are some pieces of a white lithoidal or porcelain-like appearance. They have a light greenish tone of color and a deeper green by transmitted light. A number of small vesicles or gas pores are here and there seen in the material. Under the microscope it is found to consist of glass filled with microlites; some of rather short, minute prisms of diopside with inclined extinctions and masses of feathery and fern-like forms of the same substance. There are also minute fibers whose extinction appears parallel and whose exact nature is doubtful.

OBSIDIAN.

One of the most interesting features of the collection is the presence of several specimens of jet black artificial obsidian, appearing quite similar in color, luster, and fracture to the natural obsidians from the Yellowstone Park, Mono Lake, Lipari Islands, and other well known localities. Flowage lines

or directions through the mass are indicated by parallel chains of little points around which the glass has a minute but different fracture and which thus interrupt the broad, smooth surfaces of the usual conchoidal areas.

The appearance of this black glass is so entirely unlike that of the ordinary light-green and transparent bottle glass that formed the flow that it is difficult to believe it is merely a modification of it, though positively so stated. It is, however, as will be presently shown, a curious modification of a light-green transparent bottle glass, though whether of the same melt as that which has been previously described as containing the spherulites seems doubtful. The doubt rests on chemical evidence. The first glass contains, as mentioned, only a small amount of iron, and a considerable proportion of magnesia, and diopside has crystallized from it; the qualitative analysis of the obsidian indicates much more iron, and while there is abundance of lime, magnesia is present only in minutest traces and as a result wollastonite has crystallized out in a particular layer, as will be described later. Unfortunately, in the lapse of time since the material was formed the possibility of obtaining more exact information concerning it and the conditions under which it was produced have been lost. If the statement accompanying the collection is to be trusted, then magmatic differentiation must have occurred, which seems hard to believe.

Considering the black color, it seemed at first as if the glass must have been of some other melt into which some unusual ingredient had entered which colored it black, or if a part of the flow, then one which had in some way imbibed a coloring constituent. Close inspection of a piece of this obsidian shows, however, that in a place where there are fractures, or cracks, penetrating it, if the mass is so turned to the light that the rays entering it are reflected back from the internal surface of the crack to the eye, the black color disappears and the glass, between the crack and the eye, assumes its normal sea-green transparent aspect.

The black color is due, then, not to a chemically diffused coloring matter, so to speak, in the sense that iron compounds color glass green, manganese purple, or cobalt blue, but is a mechanical effect of some kind, owing to which that light which strikes it and is not immediately reflected from the outer surface, penetrates it and is absorbed.

Many or most natural obsidians which appear black are found in thin section to be composed of a colorless glass, swarming with specks, or trichites, whose exact nature is unknown, but which many believe to be of magnetite. The idea involved is this: An obsidian is formed because the effusion and cooling have been so rapid that the ordinary rock con-

stituents have had no opportunity to begin to crystallize before the mass stiffened. But experience also shows that, in general, the more rapid the cooling the greater the number of centers of crystallization which will be set up. Now if anything should start to crystallize in magma under such conditions it would be the magnetite, ordinarily the earliest mineral of importance to form, and it would be therefore distributed through the glass in the shape of the finest dust acting megascopically as a mechanical pigment and coloring it black. The red color that many obsidians show may then be due to the complete oxidation of the magnetite to ferric oxide.

On the other hand, a study of a number of sections of various obsidians, and also of the literature, seems to indicate that the color may not be wholly due to magnetite. Zirkel,* in discussing it, considers that it is sometimes inherent in the glass (chemical so to speak) and is sometimes due to inclusions of minute size, which he describes. In the latter case the glass is colorless, and in the study of several obsidians of this character the writer has observed that the microlites, or trichites, have a higher index of refraction than the surrounding glass, as shown by Becke's method. On lowering the objective beyond the focal point they appear black, on raising it above they become illuminated and appear colorless. Consequently they are transparent and not magnetite. The greater the number of these incipient crystallizations there are, the blacker and less transparent the glass appears megascopically. The black color in this case then is due to light absorption. In one case where the slender microlites were arranged in parallel positions in streams, it was noticed that the section possessed a distinct pleochroism; when the ray vibrated across these streams it appeared colorless; when the long diameters were parallel to the ray it was distinctly brown. This is an effect of light absorption similar to that previously described under spherulites and doubtless produced in the same way. The black color of many obsidians then appears to be caused by the dispersion, total reflection, and absorption of light due to the presence of innumerable hosts of minute crystalline bodies of a higher refractive index than the glass in which they lie, such crystalline bodies being themselves colorless.

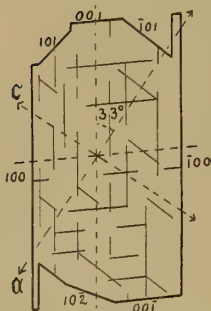
In the case of the artificial obsidian of Kane, with magnifications of 540 diameters, the microscope reveals the presence of bodies of indeterminate nature. They are so minute that no definite shape can be assigned to them, but they give a vague impression of being rudely octahedral. On lifting the objective they become strongly illuminated, on lowering they appear black. Thus they are transparent and of a higher

* *Lehrb. d. Petrog.*, vol. ii, p. 271, 1894.

index of refraction than the glass. While everywhere freely sprinkled through the field of view, as the stars appear at night in the sky, they cannot be said to swarm in the sense that, with reference to their own diameters, they closely approach one another. They exert no perceptible action on polarized light. To the absorption of light caused by the presence of these minute bodies, as with some natural obsidians, the black color of this variety of the Kane glass is ascribed.

Partly Crystallized Obsidian.—In one place there is a layer of the obsidian about 3 inches thick, which has partly crystallized. The black glass described above makes a rather clean and sharp contact with it. It is not now known whether this layer was above or below the pure glass one, but as it contains impurities on the side opposite the glass, and also on general principles, it is assumed as the bottom part of the obsidian. In the specimen it has a stony, not glassy, appearance; is of a very dark to blackish gray color, and is seen to be composed of a sort of felt of innumerable small slender-bladed crystals 2–4^{mm} long, which have a tendency to be arranged parallel to the extension of the layer. It has something of a rough resemblance to some hornblende schists.

FIG. 4.

FIG. 4. Wollastonite, section parallel to b (010).

There is no schistosity in the fracture however, which is rough and hackly. The thin section under the microscope is a very interesting one. It is composed of a pale brown glass, filled with beautiful crystallizations of the mineral wollastonite. While in general the mineral is developed as usual in long columnar forms, or plates parallel to the axis of symmetry, its growth has also been in such aggregates of sheaf-like, rosette-like, or feathery forms, that according to the way these are cut different effects are produced. The simplest case is shown in fig. 4, which gives a section parallel to b (010), across one of the bladed crystals. The faces in the zone of a (100) $\wedge$ c (001) are very sharply developed, as may be seen from the following table of angles measured against the cross-hairs:

	Meas.	Calc.
β , a (100) $\wedge$ c (001)	84°	84° 35'
a' ($\bar{1}00$) $\wedge$ t ($\bar{1}01$)	50° 30'	50° 26'
a (100) $\wedge$ v (101)	42° 30'	44° 33'
a (100) $\wedge$ α ($10\bar{2}$)	70°	69° 55'

The calculated angles are those given by Grosser* and the agreement is very good, except in ν (101), which was not so well developed as the other faces. The three cleavages parallel to 100, 001, and $\bar{1}01$ are excellent, as represented in the figure, their excellence being in the order given. The plane of the optic axes lies in the clinopinacoid and the bisectrix a makes an angle of 33° in the acute angle β with the vertical axis; Des Cloiseaux gives $32^\circ 12'$. The optical character is negative, a being the acute bisectrix. Since, according to Des Cloiseaux, the optic angle in air 2 E = about 70° , it follows that one optic axis emerges almost perpendicular to c , 001, the other at an angle of about 16° to a (100). Since both of these are good cleavages, it follows that when one examines the powder made by crushing the material, in convergent light under the microscope with crossed nicols, almost invariably each fragment exhibits the locus of an optic axis either just in, or just off, the field of view. Since the a (100) cleavage is the best, it is mostly the latter case that obtains and in the blades the long direction is the one of least elasticity.

While these crystallographic and optical properties prove the nature of the mineral, its identity was confirmed by the fact that, when powdered, it dissolves readily in hydrochloric acid and yields gelatinous silica.

It will be noted in the drawing of the crystal shown in fig. 4 that the a (100) faces are extended in a thin plate forming re-entrant angles; commonly these thin plates extend far beyond the main crystal and from each of the four corners, tapering off indefinitely; the cross section of the whole then shows an H with the vertical legs greatly extended. There may be other cross connections producing ladder-like affairs. It is also to be recalled that these extend as sheets perpendicular to the plane of the drawing, or along the b axis. Moreover the sheets are often curved and numbers of these extended plates are grouped into sheaves or rosette-like groups, and thus a variety of patterns are produced as these are cut by the section at various angles. The individual filaments as they appear in the section are commonly curved; if examined with a very high power it is seen that the curve really consists of a series of short minute straight pieces of crystal with wedge-shaped cracks between, continuity obtaining only along one edge. By this curving, and by repeated branching, arborescent, or plumose, forms are produced, and in places the glass between crossed nicols appears filled with them and seems like masses of magnificent ostrich plumes thickly scattered, the beauty of whose effect is greatly heightened by the use of the sensitive tint, which turns them brilliant blue and yellow.

* Zeitschr. f. Kryst., xix, p. 603.

These plumose forms, which are of remarkable delicacy and perfection, resemble the growths of augite in basaltic glass from Hawaii, described by E. S. Dana* ; they differ from the growths in the pitchstone of Arran in being much larger, more perfect, and in the curved or curled character of the stems, thus resembling plumes rather than ferns. They never form complete spherulites, though in places the thickly-grouped, feather-like bunches partly resemble them.

Spherulitic Crystallization.

The vast majority of the natural spherulites occur in acid, that is to say, siliceous volcanic glasses, and are composed of quartz, or feldspars, or of these two minerals in various proportions. The reason for this is because it is especially in magmas of this nature that the relation between viscosity of magma and crystal growth, which is necessary for spherulitic crystallization and which is discussed later, is apt to occur. Spherulite crystallizations may occur in basic magmas and are known in the rocks called variolites,† but so far as the writer has been able to discover, no discussion of spherulites, as such, has been made which was not primarily based on material of the kind referred to. It is natural, therefore, that in these discussions the chemical character of the magma involved and the nature of the component minerals are largely held responsible as determinant factors for spherulitic crystallization. Since such natural magmas contain, as is well known, volatile constituents, especially water vapor, a considerable rôle has been ascribed to its agency in this connection. Thus Cross‡ ascribed the origin of the spherulites in a rhyolite studied by him to the presence of a colloidal condition in the magma, due to the antecedent formation of masses of opaline silica containing the elements of feldspar, which caused their formation and globular form. Iddings§ also, in his earlier discussions of spherulites, suggests that water vapor plays an important rôle in rendering certain places in the magma less viscous and therefore more susceptible to molecular movement and crystallization. This would explain the formation of crystalline spherulites in some places, while the surrounding magma solidified as glass although at the same temperature. He says: "Hence we may conclude that the influence of the absorbed water-vapor is to render the molecular mobility of the molten magma

* This Journal, xxxvii, 441, 1889.

† Pirsson, *Petrog. of Igneous Rocks of Little Belt Mts.*, 20th Ann. Rep. U. S. Geol. Surv., Pt. III, p. 532, 1900.

‡ *Constitution and Origin of Spherulites in Acid Eruptive Rocks*, Bull. Phil. Soc. Wash., xi, 411, 1896.

§ Bull. Phil. Soc. Wash., vol. xi, p. 446, etc., 1891.

greater at a given temperature in proportion to the amount of hydration, thus permitting the crystalline arrangement of the molecules in places of greater hydration, while the surrounding less hydrated portions are becoming too viscous."

In his latest discussion of spherulitic crystallization, Iddings* again refers the conditions controlling it in acid volcanic glasses to varying amounts of water vapor—as "probably dependent on viscosity, as affected by the gas contents of a magma." In these discussions, however, the underlying idea appears to be not so much an explanation of the assumption of the spherulitic *form*, or habit of growth, as of the production of local conditions which would favor crystallization and permit the formation of one component rather than another, for in spherulitic growths in the natural volcanic glasses one must deal with quartz and feldspar.

Spherulitic crystallization in the ultimate analysis is a question of crystal form or rather *habit*. The essential thing in a typical spherulite is that from a common center crystals grow in all directions whose elongation is excessive as compared with their breadth and thickness. They may be straight rods, or branching rays, or blades, or assume arborescent shapes, all of which occur in the Kane specimens, but always tending to elongate forms, thickly crowded. The suggestion of Cross tends to assume that the spherical shape or rather area was defined before crystallization actually occurred and is thus an explanation rather of the outward form than of the inward structure. It seems highly probable that the degree of hydration in the natural acid glasses affecting the viscosity, as suggested by the writers above, plays an important rôle in determining the conditions and places for spherulitic crystallization, but in the Kane glass this agency was not present and the complication of having two mineral substances to deal with is also wanting. The question here is simply one of the conditions which determined the assumption of a certain kind of crystal habit, and the answer, in the writer's opinion, is to be found in the degree of viscosity which had been attained at the time when the saturation of the solution with the diopside molecule reached the crystallizing point. Iddings† states that the habits of crystals depend in a large degree on the viscosity of the magma, long slender prisms and branching shapes being commonly developed when it is very viscous, though he does not explain why this is so. The writer offers this explanation for the slender fibers in the spherulites of diopside in the Kane glass. The pyroxene has a prismatic cleavage and is elongate

* Igneous Rocks, vol. i, pp. 231, 233, 1909.

† Igneous Rocks, vol. i, pp. 206, 216, 1909.

in the direction of this cleavage. It is not singular in this respect, for most minerals tend to be elongate, or columnar, in the direction of pronounced cleavages. In the direction normal to the cleavage faces the molecular network has a lesser amount of cohesive attraction than in other directions and hence the cleavage. We may therefore imagine that during the process of growth the amount of molecular tension or pull exerted by the crystal upon the unorientated molecules in the magma is greater toward the end face than toward the prism, or cleavage, faces. Hence the supply of molecules upon it is more rapid and the crystal grows faster in this direction. If now the viscosity of the magma rises to such a degree that the tension toward the side faces is not sufficient to overcome it and orientate the molecules while that upon the end face is sufficiently great, then the crystal will extend itself like a long rod, or fiber, until the growing viscosity puts a stop to further progress in this direction also. The crystallizing effect of the fiber end would also be aided by the fact, that as the molecules fall into position in the geometric network, or change from the liquid to the solid state, a certain amount of heat is liberated, tending to increase the mobility of the still unfixed adjacent molecules and to render them more susceptible to crystallographic orientation. The crystals then, like a wire with a hot end, bore out into the stiffening magma in all directions, and as conditions are uniform about them they cease simultaneously and the globular shape results. This relation of habit between viscosity and cohesive attraction is also well illustrated by the wollastonite crystals in the dark glass. They extend indefinitely along the b axis perpendicular to which there is no cleavage and are also tabular to the $a(100)$ face, parallel to which the best cleavage occurs. In the fibers of feldspar in spherulites in the volcanic rocks the elongation in the majority of cases is parallel to the clino axis, the direction of the two prominent cleavages. The instances cited where the elongation is parallel to the c axis* would tend to show that the molecular attraction to the $c(001)$ face in orthoclase is greater than that to the $b(010)$ face. The fact that large crystals and especially Carlsbad twins are often tabular or elongate on the c axis also shows this. It is generally considered that the cleavage $c(001)$ of orthoclase is better than that of $b(010)$, and this would appear to make these cases an exception to the general rule. It is not clear, however, judging from the views of the writers previously stated, that viscosity is the only factor to consider in these cases, as it is in the Kane glass, as a delicate balance between several different factors may have induced

* Iddings, Spherulitic Crystallization, Bull. Phil. Soc. Wash., vol. xi, p. 456, 1891.

this particular form. Nor does the writer wish to affirm as a positive rule that in all minerals the attraction causing growth is less towards a pronounced face of cleavage than in other directions. It does, however, appear to be a rather general one.

In addition to the elongation of the fibers in spherulites there is also the branching to be taken into account. The more rapid growth of the corners and edges of crystals, due to their commanding a larger portion of the space which is supplying the crystallizing material and thus producing branching and skeleton growths, was brought to attention by Lehmann* and further elaborated by Rosenbusch† and needs no further discussion here. In the treatment of the subject by these authors, however, it is tacitly assumed that the molecular attraction towards all faces of the growing crystal is the same, or at least there is not mentioned anything to the contrary, and the view previously expressed by the writer, that this may be different on different faces, brings into play another factor.

That the molten glass had attained a considerable degree of viscosity before crystallization began is clearly indicated by the spherulites seen in figs. B and C of the plate, since it was great enough to support these denser bodies and prevent them from sinking to the bottom.

That the formation of the spherulites was a comparatively rapid process, after crystallization once started, is plainly shown by their occurrence in the manner figured in A of the plate. They were not present, of course, in the molten glass in the furnace before breakage occurred, and their appearance here in flow lines proves they had formed before flowage motion of the glass had ceased. However long a time viscous flowage may continue in larger masses of lava, in this small body of glass it must have had a relatively short period.

From the foregoing discussion it appears that the production of spherulites in an anhydrous molten glass depends upon crystallization starting from a center and proceeding outwardly in all directions at a time when the molten solution had attained such a degree of viscosity as to control the crystal habit and also upon the composition being such as to produce minerals which naturally grow in columnar forms. The time interval between this point and that where the fall of temperature increases the viscosity to such a degree as to prevent further molecular movement evidently controls the size of the spherulites. In the case of the huge spherulites described by Cross‡ from Colorado this time interval must have been relatively long.

* Ueber das Wachsthum der Krystalle, Zeitschr. f. Kryst., i, 462, 1877.

† Phys. der Min., 1885, p. 26, 4th ed., vol. 1, 361, 1904. ‡ Loc. cit.

In a sheet of molten glass the planes of cooling descend vertically into the mass so that variations of temperature from point to point become much more marked in this direction than in a horizontal one. It is also true that in the change from the liquid to the solid condition a more or less considerable contraction of volume ensues. Further, the force of crystallization is very powerful within the distance in which it acts,* and in the final stage of viscosity before the capability of molecular movement ceases the tension on the growing crystal faces must be very strong and, *per contra*, on the adjacent areas of unorientated molecules. Taking these facts into consideration, it is clear that especially toward the end of the process of spherulitic crystallization, these bodies and the glass surrounding them will be subjected to stresses which are most marked in vertical directions. Unable to withstand the tension, they may rupture, giving rise to horizontal, or longitudinal, cracks or even be pulled apart so that ovoid, or spherical, cavities are opened within them, as illustrated in fig. 3. Or the tension between them and the surrounding glass may be relieved by tangential, or radial, cracks in the latter, as also illustrated and described. Thus the layers of spherulites spread through the glass in bands by flowage become elements of inherent weakness and along them it splits into plates and thus has a laminated structure. This phenomenon is also noticed in natural rhyolite glasses, like those from Lipari and the Yellowstone Park, which cleave readily along the bands of spherulites. Iddings,† in discussing the laminated nature of such rocks, attributes it to non-homogeneity in different parts of the magma, produced by variable amounts of contained water vapors, which unlike portions by the spreading out action of flowing lavas become distributed in thin sheets. Hence arise layers of different degrees of consistency, crystalline character, etc., which condition the banded structure and cause lamination. The Kane glass, however, shows that the same lamination, though not perhaps in so high a degree, can be formed in the cooling of an anhydrous magma and that the water vapor, except where it causes layers of bubbles, as in pumice, must be an indirect rather than a direct agent in producing lamination in that it promotes more favorable conditions for crystallization.

Differentiation.—In the clear glass containing relatively few small spherulites there is a non-homogeneous quality which shows itself by drawn out streaked lines and layers, these being nowise different in color or consistency, but having dif-

* Becker and Day, Linear Force of Growing Crystals, Wash. Acad. Sci. Proc., vol. vii, p. 283, 1905.

† This Journal, vol. xxxiii, p. 43, 1887; Igneous Rocks, vol. i, p. 243, 1909.



A



B



C

SPHERULITES IN ARTIFICIAL GLASS.

ferent refractive indices, and thus becoming visible by their action on light, in the same manner that heated air-currents are visible above a source of heat, or differing currents of salt laden solutions are seen in a liquid. These streaks are small and fine and are parallel to one another, and to the chains of spherulites, in the direction of flow. Since the refractive index varies in the different layers there must be a difference in composition to occasion it. The difficulty of obtaining glass of uniform composition, through a tendency to separate into unlike portions, is one well known to makers of lenses and other users of optical glass and has been frequently described. It needs no further mention here beyond the comment that this case adds another to those which have been cited by others as a proof that the instability of molten silicate solutions furnishes a presumptive proof of the possibility of magmatic differentiation on a larger scale.

If we accept the statement, which cannot unfortunately be now verified, that the black obsidian is really a part of the same glass flow, a more striking instance of differentiation is shown in that the clear glass is rich in magnesia and poor in iron oxide while in the obsidian the reverse is the case. This difference explains very clearly why diopside crystallized out in the one and wollastonite in the other. But such a movement, provided we suppose the original molten solution to have been homogeneous, whereby magnesia and ferrous oxide are concentrated in opposite directions, while one would hesitate to say it was impossible, from all our experience gained in the study of rock-masses in which these oxides move together, seems very unlikely to say the least. And on the other hand, we do not know, in the production of glass on so large a scale, whether a sufficiently high temperature was maintained long enough to permit the molten solution to assume conditions of uniformity throughout its mass, if, on account of a difference of materials used in the making, uniformity was not present to begin with. Viewed from this standpoint, it is possible that the obsidian was part of the same flow. At all events, the material seems to indicate the possibility of obtaining in this direction, artificially, some light on the, at present, mysterious process, or set of processes, known as differentiation.

Composition of Minerals.—The use of the terms diopside and wollastonite in this paper is of course only a general one and it is not assumed that these substances are necessarily present in a pure condition. From the splendid results which have been achieved in recent years by Dr. Day and his co-workers in the Geophysical Laboratory of the Carnegie Institution concerning the properties of the lime and magnesia silicates, and the conditions under which they are formed, and

which have been published in this Journal,* it has been shown so clearly that diopside and wollastonite, as produced from molten solution, may contain variable amounts of lime and magnesia metasilicates in solid solution, that it would seem quite possible that the diopside in the Kane glass is far from being pure in composition. The analytical test proves that the wollastonite is relatively a pure compound, and the optical data, so far as they go, agree with this view.

It is evident from the works quoted that the temperature of the glass, when the wollastonite crystallized, must have been lower than 1190° , since this is the inversion point of the mineral to pseudo-wollastonite, which alone exists above that temperature and up to 1512° , its melting point. The melting point of diopside is 1380° and the temperature of the molten solution was therefore originally above this point; this of course is to be expected, even though a flux is used to help carry the quartz sand and lime carbonate into solution.

Summary.—The study of the accidental flow of molten bottle-glass at Kane, Penn., has brought out the following chief points:

That spherulites of varying size and character and consisting of diopside may be formed in an anhydrous molten solution by rapid cooling.

That the spherulitic type of crystallization appears to be conditioned by the relation of crystal habit and properties to the viscosity of the magma. The spherulites are of rapid growth.

That the brown color, which many spherulites exhibit by transmitted light, is a phenomenon of light absorption.

That obsidian may be artificially produced from a clear glass and that its black color is a phenomenon of light absorption.

That artificial wollastonite may exhibit certain characters which are described.

Sheffield Scientific School of Yale University,
New Haven, Conn., April, 1910.

* Day, Shepherd and Wright, *The Lime-Silica Series of Minerals*, vol. xxii, pp. 265-302, 1906. Allen, White and Wright, *On Wollastonite and Pseudo-wollastonite, Polymorphic Forms of Calcium Metasilicate*, vol. xxi, pp. 89-108, 1906. Allen, White, Wright and Larsen, *Diopside and its Relation to Calcium and Magnesium Metasilicates*, vol. xxvii, pp. 1-47, 1909.

ART. VIII.—*The Inversion of Temperature Amplitudes and Departures in the United States*; by FRANK H. BIGELOW.

The Phenomenon of Temperature Inversion.

IN several of my papers on the temperatures of the United States, I have given preliminary data showing generally that there is a distinct tendency to invert the temperature variations in the United States relatively to the solar conditions as given in the annual numbers for the frequency of the sunspots and solar prominences. These are, this Journal, December 1894, inversion of temperatures in the 26·68 day solar magnetic period; Weather Bureau Bulletin No. 21, 1898, Solar and Terrestrial Magnetism, pp. 121 and foll.; Monthly Weather Review, November 1903, Synchronism of the solar prominences with the terrestrial barometric pressures and the temperatures. These papers indicated that the response to a change in the solar energy when received at the earth is by no means simple, but that the terrestrial effect is much complicated by the circulation of the atmosphere, whereby opposite temperature effects are produced in different latitudes. Thus, an increase of solar action produces an increase of temperature in the Tropics, but a relative decrease in the temperate zones. This view was explained more fully in two papers, this Journal, May, 1908, and April, 1910. Bulletin S, U. S. Weather Bureau, 1909, contains the temperature data of the United States, 1873–1905, reduced to a homogeneous system, which is continued in the Annual Reports of the Chief of the Weather Bureau, and these temperature data have been used in preparing Table I of this paper. We have the independent records of upwards of 100 stations from which the annual departures on the 33-year normal are computed. These annual departures were entered on base maps of the United States, and lines of equal departures were drawn. This system of departures for the United States is so smoothly developed that it is very easy to draw the lines of equal temperature variation. There is one map for each month, and one for the year, from January, 1873, to December, 1909, making $37 \times 13 = 481$ separate charts, upon each of which there are something like 100 entries of the temperature departures. An example is given for May, 1896. Each entry on fig. 1 is found by subtracting the 33-year normal of the station from the monthly mean given in the Bulletin S table for the several stations. An inspection of these 100 independent values of the departure shows that there is a remarkably harmonious agreement among them, which implies that the

temperature system of the United States is really homogeneous for 37 years, and that the data derived from the large cities is indistinguishable from those obtained in localities affording more favorable exposure for the meteorological instruments. Similarly, the 481 charts available have spread out the history of the mean monthly temperature variations from the 33-year normal for the period January, 1873, to December, 1909, inclusive, and it is our problem to analyze and discuss this valuable material.

The Temperature Departures for the United States.

These charts are available for several purposes. (1) They permit the adjustment of the temperatures of a short record station to the 33-year normal by the following process: Take the means of the short record series of temperatures month by month, and their departures ($v_i - v_s$); take the departures by scaling from the charts for the station during the same interval of time ($v - v_o$); if the sum of the differences, $\Sigma [(v_i - v_s) - (v - v_o)] = 0$, equals zero, it follows that the mean temperature of the short series is the same as that of the 33-year normal series, because the departures average the same amount; if these mean sums are not equal it is easy to compute a value for v_s which will make them equal, and then $v_s = v_o$. The departures ($v - v_o$) are derived from the charts of long record, while those for ($v_i - v_s$) are derived from the station short record, so that it is only necessary to adjust the latter to the former by correcting v_s in such a way as to give the same system of departures for the station record that appears on the charts on the average.

(2) It is evident that these charts constitute the record for a small area of the earth's surface of the temperature changes going on over continents and oceans in both hemispheres, eastern and western, or northern and southern, such as meteorologists require for the study of problems in the world-departure of temperature. The Weather Bureau now possesses tables from which correlative variation charts can be constructed for the barometric pressures, the temperatures, the vapor pressures, and the precipitation in the United States, 1873 to 1910, and they will be utilized in all important world problems of the atmosphere for many years to come. Only those who have performed the great labor of reconstructing the massive records in meteorology for the United States for this period of 37 years can appreciate the work that has been accomplished in this respect. It now gives us a very solid foundation for studies of every description in solar and terrestrial physics, and it is hoped that similar data will soon be furnished by other well-organized weather services.

TABLE I.—THE TEMPERATURE DEPARTURES FOR THE UNITED STATES, 1873-1909.

Year	Jan.	Feb.	Mch.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	An- nual	Sums	Diff.
1873	+ 12	+ 14	+ 24	+ 1	+ 2	+ 48	+ 12	+ 35	+ 2	+ 1	+ 10	+ 20	+ 181	471	-109
	- 42	- 3	- 20	- 54	- 32	- 2	- 4	- 3	- 40	- 40	- 40	- 10	- 290		
1874	+ 60	+ 30	+ 20	+ 4	+ 32	+ 40	+ 32	+ 28	+ 15	+ 12	+ 14	+ 10	+ 297	426	+ 168
	- 1	- 8	- 15	- 64	- 3	- 1	- 2	- 9	- 10	- 6	- 3	- 7	- 129		
1875	+ 6	+ 1	+ 3	+ 4	+ 18	+ 18	+ 15	+ 1	+ 1	+ 25	+ 12	+ 75	+ 179	757	-399
	- 145	- 144	- 63	- 54	- 4	- 12	- 15	- 30	- 36	- 25	- 48	- 2	- 578		
1876	+ 80	+ 75	+ 3	+ 10	+ 12	+ 18	+ 28	+ 35	+ 5	+ 10	+ 6	+ 1	+ 283	628	- 62
	- 5	0	- 95	- 12	- 7	- 8	- 2	- 15	- 27	- 35	- 24	- 115	- 345		
1877	+ 16	+ 144	+ 26	+ 5	+ 8	+ 12	+ 27	+ 30	+ 24	+ 12	+ 9	+ 128	+ 441	642	+ 240
	- 24	- 5	- 36	- 24	- 32	- 20	- 1	- 1	- 3	- 24	- 28	- 3	- 201		
1878	+ 70	+ 144	+ 165	+ 64	+ 6	+ 20	+ 49	+ 52	+ 10	+ 5	+ 20	+ 1	+ 656	842	+ 470
	- 12	- 5	0	- 2	- 28	- 17	- 1	0	- 18	- 18	- 5	- 80	- 186		
1879	+ 23	+ 42	+ 80	+ 25	+ 42	+ 18	+ 37	+ 10	+ 18	+ 72	+ 20	+ 16	+ 403	602	+ 204
	- 17	- 20	- 1	- 12	- 6	- 4	- 1	- 8	- 26	- 1	- 13	- 90	- 199		
1880	+ 156	+ 63	+ 20	+ 21	+ 45	+ 20	+ 2	+ 12	+ 3	+ 1	+ 1	+ 2	+ 346	795	-103
	- 2	- 18	- 35	- 24	- 12	- 5	- 9	- 15	- 25	- 10	- 150	- 144	- 449		
1881	+ 6	+ 22	+ 18	+ 20	+ 62	+ 35	+ 28	+ 38	+ 54	+ 45	+ 14	+ 95	+ 437	799	+ 75
	- 72	- 84	- 50	- 42	- 1	- 10	- 7	- 12	- 20	- 23	- 40	- 1	- 362		
1882	+ 49	+ 98	+ 35	+ 16	+ 2	+ 12	+ 9	+ 11	+ 9	+ 35	+ 10	+ 14	+ 300	524	+ 76
	- 14	- 24	- 18	- 14	- 44	- 8	- 15	- 10	- 7	- 20	- 25	- 25	- 224		
1883	+ 2	+ 25	+ 20	+ 8	+ 1	+ 20	+ 15	+ 6	+ 10	+ 20	+ 30	+ 38	+ 195	551	-161
	- 90	- 72	- 24	- 20	- 50	- 8	- 6	- 12	- 30	- 36	- 6	- 2	- 356		
1884	+ 2	+ 35	+ 15	+ 2	+ 22	+ 22	+ 12	+ 5	+ 30	+ 48	+ 11	+ 7	+ 211	590	-168
	- 57	- 40	- 20	- 30	- 12	- 20	- 18	- 22	- 24	- 4	- 6	- 126	- 379		
1885	+ 5	+ 24	+ 40	+ 20	+ 7	+ 4	+ 12	+ 3	+ 8	+ 12	+ 40	+ 42	+ 217	544	-110
	- 80	- 66	- 45	- 6	- 21	- 25	- 5	- 30	- 13	- 25	- 3	- 8	- 327		
1886	+ 3	+ 72	+ 3	+ 18	+ 35	+ 9	+ 20	+ 16	+ 7	+ 30	+ 2	+ 24	+ 239	630	-152
	- 96	- 20	- 36	- 15	- 4	- 22	- 9	- 3	- 11	- 18	- 85	- 72	- 391		
1887	+ 24	+ 42	+ 54	+ 15	+ 60	+ 30	+ 40	+ 5	+ 10	+ 9	+ 14	+ 4	+ 307	604	+ 10
	- 72	- 70	- 19	- 8	- 1	- 4	- 2	- 14	- 12	- 39	- 8	- 48	- 297		
1888	+ 6	+ 84	+ 1	+ 45	+ 12	+ 12	+ 15	+ 9	+ 30	+ 12	+ 11	+ 42	+ 279	664	-106
	- 112	- 9	- 90	- 10	- 43	- 7	- 6	- 20	- 30	- 30	- 22	- 6	- 385		
1889	+ 48	+ 2	+ 84	+ 45	+ 7	+ 18	+ 12	+ 15	+ 3	+ 18	+ 13	+ 135	+ 400	676	+ 124
	- 25	- 45	- 9	- 1	- 18	- 32	- 15	- 17	- 40	- 32	- 39	- 3	- 276		
1890	+ 62	+ 65	+ 7	+ 15	+ 16	+ 25	+ 24	+ 2	+ 6	+ 2	+ 72	+ 55	+ 351	611	+ 91
	- 48	- 15	- 40	- 3	- 38	- 7	- 8	- 29	- 30	- 16	- 1	- 25	- 260		
1891	+ 102	+ 40	+ 1	+ 31	+ 9	+ 7	+ 3	+ 13	+ 45	+ 13	+ 14	+ 65	+ 343	707	- 21
	- 24	- 75	- 75	- 6	- 35	- 22	- 42	- 20	- 3	- 22	- 25	- 15	- 364		
1892	+ 9	+ 85	+ 18	+ 4	+ 2	+ 11	+ 8	+ 7	+ 22	+ 15	+ 16	+ 2	+ 199	528	-130
	- 35	- 1	- 32	- 30	- 81	- 20	- 15	- 12	- 12	- 10	- 27	- 54	- 329		
1893	+ 32	+ 12	0	+ 20	+ 1	+ 25	+ 15	+ 3	+ 10	+ 4	+ 2	+ 35	+ 159	582	-264
	- 60	- 63	- 60	- 70	- 33	- 15	- 4	- 24	- 22	- 22	- 30	- 30	- 423		
1894	+ 32	+ 7	+ 57	+ 30	+ 20	+ 25	+ 26	+ 18	+ 15	+ 28	+ 30	+ 48	+ 336	556	+ 116
	- 29	- 64	- 10	- 2	- 10	- 25	- 11	- 20	- 12	- 3	- 18	- 16	- 220		
1895	+ 2	+ 16	+ 18	+ 45	+ 15	+ 15	+ 1	+ 10	+ 30	+ 7	+ 7	+ 12	+ 178	604	-248
	- 108	- 75	- 32	- 3	- 15	- 30	- 40	- 9	- 20	- 45	- 19	- 30	- 426		
1896	+ 52	+ 117	+ 4	+ 45	+ 49	+ 20	+ 16	+ 18	+ 1	+ 10	+ 27	+ 56	+ 415	712	+ 118
	- 7	- 2	- 42	- 24	- 18	- 5	- 9	- 6	- 45	- 32	- 100	- 7	- 297		
1897	+ 6	+ 28	+ 35	+ 12	+ 24	+ 5	+ 15	+ 15	+ 64	+ 49	+ 18	+ 7	+ 278	527	+ 29
	- 20	- 8	- 60	- 9	- 30	- 22	- 17	- 18	- 3	- 8	- 24	- 30	- 249		
1898	+ 39	+ 77	+ 45	+ 18	+ 14	+ 20	+ 14	+ 19	+ 21	+ 7	+ 2	+ 2	+ 278	568	- 12
	- 35	- 8	- 33	- 28	- 24	- 4	- 9	- 5	- 6	- 42	- 36	- 60	- 290		
1899	+ 22	+ 1	+ 1	+ 16	+ 20	+ 12	+ 4	+ 30	+ 16	+ 30	+ 110	+ 6	+ 269	724	-186
	- 6	- 140	- 140	- 24	- 30	- 13	- 14	- 26	- 14	- 12	- 1	- 25	- 455		

TABLE I.—THE TEMPERATURE DEPARTURES FOR THE UNITED STATES, 1873-1909—*Concluded.*

Year	Jan.	Feb.	Mch.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	An- nual	Sums	Diff.
1900	+ 108 - 2	+ 9 - 42	+ 33 - 30	+ 48 - 23	+ 54 - 1	+ 42 - 9	+ 2 - 13	+ 38 - 20	+ 28 - 15	+ 75 - 3	+ 30 - 24	+ 59 - 2	+ 532 - 134	716	+ 348
1901	+ 62 - 1	+ 7 - 49	+ 40 - 14	+ 12 - 35	+ 32 - 19	+ 25 - 23	+ 75 - 2	+ 21 - 5	+ 6 - 14	+ 23 - 4	+ 30 - 20	+ 12 - 36	+ 345 - 222	567	+ 123
1902	+ 48 - 12	+ 40 - 45	+ 63 - 12	+ 19 - 13	+ 42 - 5	+ 12 - 22	+ 7 - 19	+ 17 - 13	+ 2 - 46	+ 30 - 2	+ 64 - 5	+ 7 - 70	+ 351 - 264	615	+ 87
1903	+ 50 - 3	+ 12 - 98	+ 45 - 15	+ 9 - 17	+ 10 - 23	+ 14 - 47	+ 3 - 25	+ 7 - 20	+ 1 - 45	+ 30 - 10	+ 14 - 22	+ 18 - 56	+ 213 - 381	594	- 168
1904	+ 18 - 40	+ 40 - 55	+ 45 - 9	+ 10 - 40	+ 12 - 13	+ 3 - 32	+ 1 - 30	+ 5 - 25	+ 20 - 9	+ 20 - 9	+ 48 - 10	+ 12 - 30	+ 234 - 302	536	- 68
1905	+ 15 - 56	+ 10 - 70	+ 135 - 1	+ 12 - 25	+ 13 - 30	+ 11 - 23	+ 9 - 30	+ 20 - 7	+ 40 - 1	+ 5 - 37	+ 38 - 8	+ 12 - 38	+ 320 - 326	646	- 6
1906	+ 90 - 2	+ 60 - 8	+ 1 - 90	+ 42 - 5	+ 4 - 12	+ 8 - 30	+ 30 - 24	+ 20 - 12	+ 50 - 3	+ 17 - 25	+ 17 - 12	+ 55 - 16	+ 394 - 239	633	+ 155
1907	+ 66 - 80	+ 72 - 23	+ 90 - 7	+ 9 - 63	+ 7 - 85	+ 5 - 45	+ 4 - 15	+ 12 - 30	+ 13 - 17	+ 19 - 18	+ 45 - 13	+ 32 - 0	+ 80 - 396	841	+ 49
1908	+ 100 - 1	+ 48 - 20	+ 80 - 0	+ 50 - 2	+ 9 - 36	+ 7 - 42	+ 20 - 17	+ 4 - 19	+ 50 - 6	+ 16 - 24	+ 52 - 5	+ 30 - 20	+ 466 - 192	658	+ 274
1909	+ 48 - 16	+ 64 - 4	+ 18 - 18	+ 6 - 35	+ 1 - 36	+ 10 - 4	+ 9 - 24	+ 28 - 6	+ 15 - 10	+ 12 - 16	+ 90 - 1	+ 2 - 108	+ 303 - 278	581	+ 25

Mean temperature amplitude number..... 629

(3) These charts, in a more restricted problem, enable us immediately to test the phenomenon of the inversion of temperatures in the United States relative to that in the tropics, and to the variation of solar energy, whereby the force function of the circulation in controlling the local temperatures of the temperate zones can be fully realized.

It is necessary to integrate in a simple way the total effect of the temperature variations in the United States, by months and by years. We may conceive the temperature charts to represent cones, or topographical volumes of departures, and the volume for each month may be taken approximately,

$$\frac{1}{3} A : d_{\max}$$

where A is the area of the region covered by a departure of one sign, and $d_{\max}$ is the maximum temperature variation at the apex, or practically the altitude of the cone. Since we are now seeking only relative numbers, the factor $\frac{1}{3}$ can be dispensed with as pertaining merely to the scale of the diagrams to be drawn, which is an indifferent matter. Thus, on fig. 1, take the area of the United States equal to 10; assume proportional parts for the positive and negative areas of departure, as 7 for the eastern or positive region, and 3 for the western or neg-

ative region; the positive maximum departure, not necessarily the highest station, is taken as 7 degrees, so that we have $7 \times 7 = +49$ to represent the strength of the positive temperature departures during the month, May, 1896, in the United States; the maximum negative departure for the western districts is about 6 degrees, so that $3 \times (-6) = -18$ represents the negative departure number for the same month; the sum of these without signs, $49 + 18 = 67$, is the total average *amplitude*, that is the amount by which the temperature system departed from the normal in a series of high and low

FIG. 1.

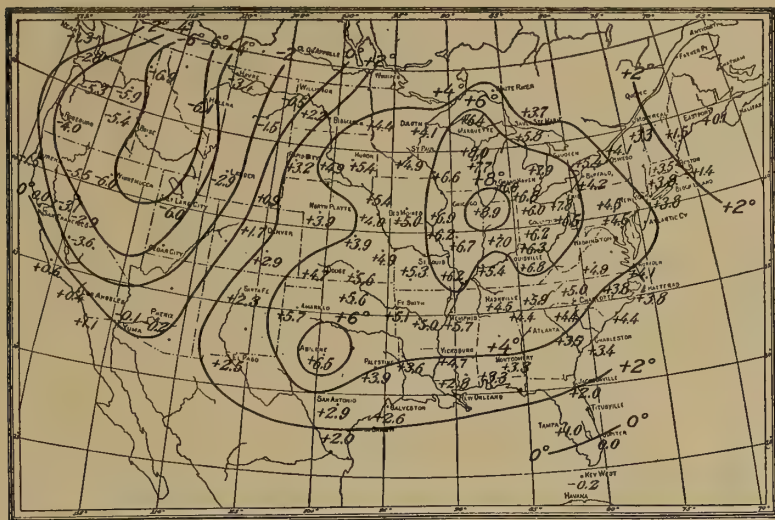


FIG. 1. Temperature Departures, May, 1896.

481 similar charts have been drawn, giving the temperature variations in the United States from January, 1873, to December, 1909.

waves; the sum of these numbers with signs, $+49 - 18 = +31$, gives the average temperature *excess* for the United States, showing that this region averaged warmer than the normal for the month. Similarly, the numbers in Table I represent the relative changes in temperature for the United States month by month for 37 years, 1873 to 1909, inclusive. It can be seen by an inspection of Table I, that :

(1) It is not possible always to treat the United States as a temperature unit in the midst of the world-departure (Newcomb), because there are many months when, as May 6, 1896, this region is not all warmer, or all colder, than the normal. There is a tendency for the temperature to oscillate about a sort of nodal line on the eastern edge of the Rocky Mountain Plateau; it sometimes happens that the interior of the United

States is of one departure sign, while the Coast States, Atlantic, Gulf of Mexico, Pacific, in whole or in part, are of the opposite sign.

(2) The strength of the *amplitudes* in winter is about twice as great, sometimes three times as great, as in the summer. In the winter the sun and the warm zones withdraw to the south, and the cold polar air moves southward. The strength of amplitude means that alternately warm and cold areas of air, warm cyclonic streams from the south, and cold anticyclonic streams from the north, pass over the United States in a turbulent circulation, the crests and hollows further apart in some years than in others. If the mean amplitude is 629, then the range in amplitude is from 426 in 1874 to 842 in 1878, or 1907, or 66 per cent for the entire series. In some months the maximum temperature departure is between 20° and 25° F., in other months only 2° or 3° F. The fundamental question is whether these variations are purely accidental or not, and this will be taken up in the following section.

(3) The *excesses* of temperature for the United States as a whole are shown in the last column of Table I, the maximum relative number being +470 in 1878 and -399 in 1875, indicating that during some years the temperature is maintained above the normal or average, and below the normal in others. The important point is to correlate the amplitudes and the excesses with solar phenomena in order to learn whether there is synchronism annually or not, and if any to classify its laws.

Synchronism between the variations in the numbers representing the frequency of the solar prominences, the sun-spots, the European terrestrial magnetic field, and the amplitudes or excesses of the temperature departures in the United States.

The curves representing these *frequency numbers* are brought together in fig. 2. The curve of solar prominences is plotted from Table 2, this Journal, May, 1908, p. 417; that for the European magnetic field is from Table 3, same paper; that for the sun-spot numbers is from Wolfer's frequency numbers; that for the temperature amplitudes is from the 15th column of Table 1 of this paper; and that for the temperature excesses is from the last column of the same table. I have not had an opportunity to extend the first two curves, of the prominences and the magnetic field, beyond the year 1905, as should be done. These curves are derived from relative numbers, and they are plotted on independent scales. The heavy mean line represents the consecutive *means* of the long-period, while the variations between this line and the original curve give the short-period *residuals*. It should be carefully noted that the curves of the temperature amplitudes and excesses are plotted inversely to the three other curves.

The synchronism in the long period between the two solar curves and three terrestrial curves cannot be questioned, that for the magnetic field being direct, and those for the temperature system of the United States being inverse. This result confirms the data and conclusions of my papers of 1894, 1898, 1903, mentioned above. The synchronism between the curves

FIG. 2.

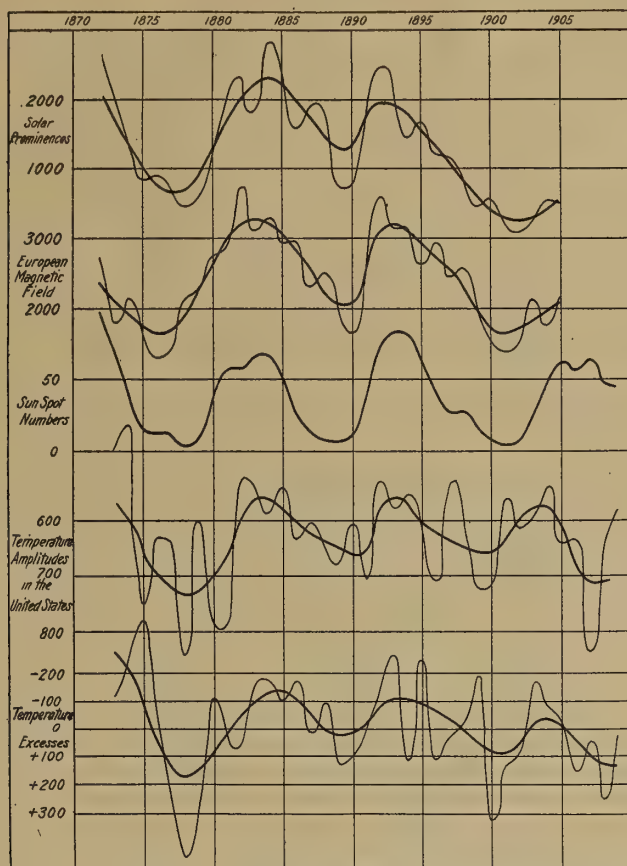


FIG. 2. Prominences, magnetic field, sun-spots and the temperature amplitudes and excesses in the United States.

of short period is not so well pronounced as for the long period, and that for several reasons. The prominences and the magnetic curve are only approximate measures of the true solar radiation output, for which they stand as substitutes. We have no long-continued series of homogeneous radiation observations from which to construct a curve representing the gram calories

per square centimeter per minute, that is the actual energy of the incoming solar radiation, and we must for some years be content with the available data. The solar prominence numbers are from the Italian spectroscopic observations on the edge of the solar disk, and these are only rough records of the total action of the solar mass as an emitter of radiant energy. Furthermore, the prominences break out earlier in the middle latitudes than near the equator or the poles, so that the general summation of prominence numbers obscures the times of free efficient emission to the earth. It is evident that systematic spectroheliograph observations of the face of the sun should be made in favorable climates, and the records should be carefully studied for the variations of the emission of solar energy by months and by years. The European magnetic field is represented by the mean horizontal force variations at a few stations, three to five, whereas the mean magnetic variation should be computed for all three components at about 10 stations for the entire earth. It is proper to infer that the precise synchronism shown between the prominences, sun-spots, and magnetic field in the long period can be extended to the short period by the expenditure of sufficient well-directed labor. The temperature curves match the short-period variations of the solar curves approximately, that is enough to recognize the same sequence of crests for each. We have shown that the temperature data is in itself of the highest order. On the other hand, it suffers from considerable unsteadiness as regards its synchronism with the solar energy on account of the inversion effects produced by the atmospheric circulation. The variations of temperature are direct with the solar energy in the Tropics, but inverse in the temperate zones. It follows that the high pressure belt is the node of this temperature effect, where the variation is indifferent. Since this belt is due to the circulation, and since the location of the belt in the United States is loosely defined, it is evident that some uncertainty in the temperature amplitudes and excesses must be expected. This high pressure belt usually runs from the Florida peninsula to northern California, but it is much broken up by the anticyclonic and cyclonic circulation through which the air from the Tropics mixes with that from the temperate zone.

It is easy to see that if these several curves could be suitably perfected, it would not be difficult to assert that certain coming years would be prospectively warmer or colder than usual. The years of maximum solar energy are years of minimum temperature and minimum amplitude. An increase of energy from the sun on the Tropics brings down colder air in the temperate zone and holds it more firmly at the surface of the earth, and the cold high areas are in excess, the winter and

summer being cooler. The minimum solar action is followed by warmer seasons in the United States, a greater amplitude in the circulation of the warm and cold areas, and a more pronounced system of warm leakage currents from the Gulf of Mexico upon the Mississippi Valley. It is, also, seen that the succession of minor crests is usually about three years, this being the 3-year period first described by Bigelow in 1894.

FIG. 3.

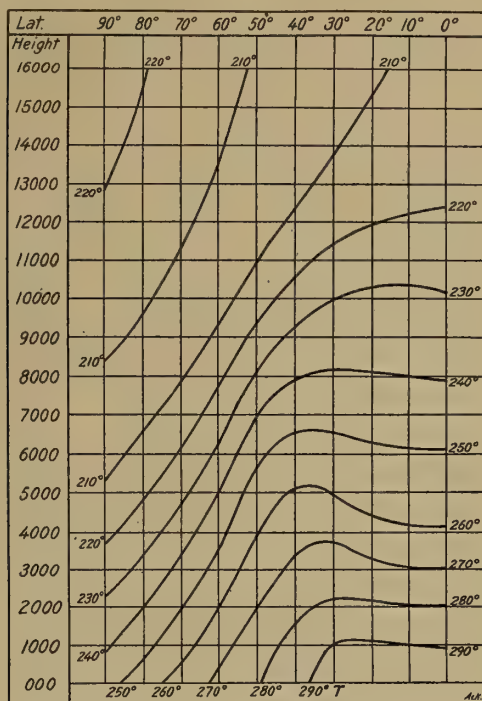


FIG. 3. The location of the mean annual isotherms in the earth's atmosphere.

The Cause of the Inversion of Temperatures.

In order that the cause of this important inversion of temperatures in the United States may be better understood, I will produce from my other unpublished studies on the General Circulation a diagram of the distribution of the mean annual temperatures in the atmosphere, as derived from balloon and kite ascensions, and from a study of the equations of motion. The vertical scale of the drawing is greatly magnified in fig. 3, in order to bring out the fundamental facts.

Imagine the quadrant of the earth's atmosphere between the equator and the poles to be rolled out into straight lines, and to extend from the surface to 16,000 meters in altitude. Then, the annual mean isotherms are disposed as indicated, subject to modification in details owing to the present lack of data, especially in the Tropics and the polar zones. The following facts should be noted: (1) In the lower levels the maximum temperature is at a higher altitude in latitude 30° to 40° than to the north or south of it; (2) the general depression of temperatures in the Tropics is due to the ascending circulation and adiabatic cooling; (3) the circulation in the Tropics is westward, because the isotherms rise upwards in going north and parallel to the earth's axis; (4) the circulation in the temperate zone is eastward for the opposite reason (see paper, *Monthly Weather Review*, January, 1904); (5) the rate of circulation depends upon the density of the isotherms in a line parallel to the earth's axis; (6) it is a maximum westward at the elevation 3000 to 4000 meters in the Tropics decreasing downwards and upwards, and reversing to eastward at about 10,000 meters (*M. W. Review*, April, 1904); (7) it increases upwards in the eastward drift of the temperate zones to about 12,000 meters and then falls off, as first shown in the *International Cloud Report*, 1898; (8) the chief function of the westward drift in the Tropics is to counteract by its motion the adiabatic cooling of the ascending air; (9) the chief function of the eastward drift is by its motion to hold the heated air of the tropic zone away from the polar region; (10) the small polar overflow in the upper levels is restricted to latitudes 50° or 60° by this circulation; (11) there is no pronounced upper poleward current and no well-defined lower equatorward current, with a neutral plane separating them, as Ferrel assumed in his canal theory; (12) the leakage currents from the Tropics to the temperate zones may occur in all levels, and then the centers of action and the wandering cyclones and anticyclones are formed; (13) the momenta of motion are continuously being readjusted between temperature and circulation to keep their sum a constant, and the angular rotation of the earth on its axis a constant; (14) in case the solar energy raises the temperature of the Tropics, with its westward drift, it follows that in the temperate zones there is an increase of eastward drift, a downflow of air, an increase of cold areas, and a decrease of amplitudes and the leakage currents; (15) an inversion of temperature in the temperate zone is a necessary result of this circulation, to balance an increase of temperature in the Tropics from the solar radiation energy. This, then, accounts for the many discrepancies which have been announced by investigators when comparing station records directly with the

sun-spot numbers. It must be fully admitted that meteorologists have an exceedingly complex problem before them, but in view of the valuable results to be derived from a correct forecast of seasonal weather conditions, they will be justified in pursuing these studies to a practical conclusion.

Observations on the Solar Radiation and their Interpretation.

It will be seen from the foregoing statement of the several lines of correlated phenomena that the continuous record of the solar radiation is the missing link in the chain. The prominences and the sun-spots are products of the outgoing radiant energy and the accompanying solar circulation; the magnetic field variations are one result of the absorption of the incoming radiation in the earth's atmosphere, and the temperature changes are another product of it, linked up with the circulation, and thence with the barometric pressure and weather conditions generally. The study of the entire series of observational problems is greatly hindered at every turn by the instrumental expense of securing the necessary original observations, and the complicated results to be interpreted. It constitutes the greatest world problem for future generations to more perfectly work up and utilize. At present the magnetic field, all things considered, is the most suitable for the practical foundation. We have numerous magnetic observatories in all parts of the world, and the observations are easily secured. The magnetic variations are direct products of the incoming radiation through the process of ionization and electric currents, but there is a regional assorting going on in the earth's atmosphere, part of the incoming energy being transformed in the outer, thin, dry layers, and another part in the lower, dense, moist layers of the earth's atmosphere. Certain corpuscles and cathode rays may have special, irregular operations in the outer layers to produce spasmodic magnetic storms, but it is the transformation of energy in the lower layers that are chiefly concerned with the diurnal and the annual periodic variations of the magnetic field. We have only to interpret these in terms of solar radiation and terrestrial circulation to connect up the two branches of this subject.

The direct observations on the incoming solar radiation, by means of the bolometer readings on the individual rays of the spectrum, and the pyrheliometer on the total or integrated heat energy, are beset with unusual difficulties, partly instrumental and partly meteorological. The splendid progress made by the Smithsonian Astrophysical Observatory in developing a reliable instrumental equipment makes us hopeful of a practical result in respect to the observations. The meteorological problem, depending upon the temporary constituents of the

atmosphere, is a subject of much perplexity. To illustrate the point we refer to fig. 4. Draw the black body curves of radiation for 7000° T and for 6000° T , by the Wien-Planck formula; lay down the curve of bolometer observations for a high mountain, as Mt. Whitney (Abbot) or Mt. Wilson (Abbot), in I, and for sea level, as Washington (Langley-Abbot), II. Abbot reports that his recent high and low altitude observations on the same day agree for the three level observations at Washington, Mt. Wilson, Mt. Whitney in producing a *total* amount of solar radiant energy equal to

FIG. 4.

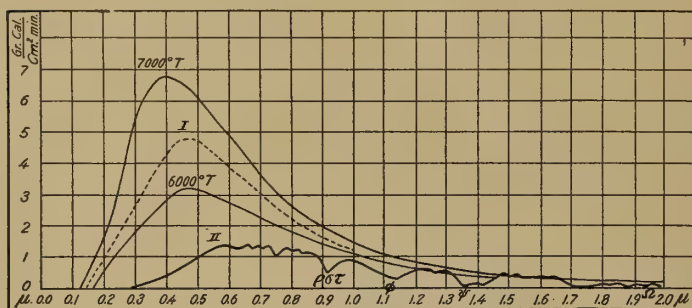


FIG. 4.—Black body radiation at 7000° T and 6000° T . Observed radiation on a high mountain (I) and at sea level (II).

about 1.92 gram calories per cm^2 per minute on the outermost layer of the earth's atmosphere. The depletion of the incoming radiation is chiefly by scattering, and it is progressive with the depth, the density and the impurity of the atmosphere, as determined by the dust, ice, and vapor contents, with the atoms and molecules of the gases themselves. In a word, the short waves are most heavily depleted and that progressively with the length of path, cutting off the apex of the pure energy curve in an irregular manner, so that it is very difficult to find the value of the maximum wave length from the observations, which we wish to introduce in the general formula,

$$T \cdot \lambda_{\max} = \text{Constant},$$

so as fully to determine the temperature of the radiating black body, responsible for the energy reaching the earth on a given date. Unless the crest of the radiation curve is found accurately, it will not be possible to assign any definitive temperature to the solar envelope with enough precision to enter into competition with the curves of fig. 2, in the forecast of weather conditions. Furthermore, the evidence of the observations seems to be at present, that the incoming radiation does not fit

the ordinates of the black body at any one temperature. The wave lengths of the bolometer curve above $1.0\ \mu$ seem to require by their greater length a solar temperature of about 7500° T , while the wave lengths of the curve from $0.00\ \mu$ to $1.00\ \mu$ seem to be satisfied with something like 6500° T . If the sun is not radiating as a pure black body, as is very likely to be the fact, it follows that the study of the solar energy of radiation is an excessively complex problem. There is evidence from the prominences that the sun has an excess of energy along one diameter and a defect along the other at right angles to it; also, from the magnetic field that the areas of heat in solar longitude, while very irregular like incipient oceans and continents, are yet capable of classification; and, from the spectro-scope that the great variations in the angular velocities at the photosphere, as 26.7 days at the equator to 31.0 days at the poles, or 26.0 near the level of the upper chromosphere over the equator to 29.0 days at the poles. These point to great changes in the local solar mass temperatures from place to place, though they may be deep seated. Such variations of the heat of the radiation energy at the sun, and of the absorbing and depleting capacities of the earth's atmosphere, render the problem of direct radiation measures one of exceptional difficulty. On the other hand, we have in the earth's magnetic field one of the most sensitive, natural instruments for registering the effects of solar radiant energy, which will be utilized before long in its highest functions. If ionization is a direct product of radiation, and it is registered accurately though indirectly in the magnetic field, it follows that this is our easiest approach to a working method of handling the materials in questions. It will doubtless require much more labor to remove some of the barriers that still stand in our way. The simple or superficial application of the standard formulas of radiation to the temperature indicated in fig. 3, will show how far we are from accounting for this distribution by any of the elementary methods heretofore discussed. It is necessary to separate the circulation effects from the radiation effects, and to separate the incoming radiation effects from the outgoing radiating effects. As none of these steps have yet been taken, we may consider the subject of the relations between radiation, temperature and circulation as virgin ground for an extensive research.

It is well to note the growth of interest and conviction in the minds of students regarding the practical validity of this solar-terrestrial problem. We have only to recall the numerous papers on the subject in recent years, besides those of the writer, by Langley, Abbot, Fowle, Lockyer, Clayton, Clough, Artowski, Merecki, and the several International Commissions on Solar Physics and Meteorology.

U. S. Weather Bureau, Washington, D. C.

ART. IX.—*The Effect of the Presence of Alkalies in Beryl upon its Optical Properties*; by W. E. FORD.

THE attention of the writer was called to the subject of the effect of the presence of alkalies in beryl upon its optical properties by a note in an article by Lacroix* on the tourmaline-bearing pegmatite veins of Madagascar. A description is given there of a rose-colored beryl which possessed unusually high values for its indices of refraction and specific gravity, and which on qualitative examination showed the presence of alkalies, notably caesium. The assumption naturally followed that these abnormal values for the refractive indices and specific gravity were due to the presence of the alkalies in the mineral. This seemed a point of sufficient interest and importance to merit further investigation.

The rôle played by the alkalies in beryl was determined in this laboratory, a number of years ago, through a series of analyses by Penfield,† and later by the same investigator and Sperry.‡ Specimens of the beryls rich in alkalies upon which these analyses were made are preserved in the Brush collection, and in two cases yielded material suitable for optical investigation. It was possible to make an orientated prism and to measure the indices of refraction of the beryl from Willimantic, Conn., analyzed by Penfield,‡ and also of the caesium beryl from Hebron, Maine, analyzed first by Penfield,† and then later by Wells.§ In addition to these, two other beryls were investigated, first the pink beryl from San Diego Co., California, in which the writer determined qualitatively some years ago the presence of alkalies,|| and second, the rose beryl from Madagascar, presumably the same as described by Lacroix. Specimens of the Madagascar beryl of gem quality were generously placed at the writer's disposal by Dr. G. F. Kunz.

An analysis was first made of the pink beryl from Mesa Grande, San Diego Co., California, the material being furnished by an irregular fragment of gem quality which was presented to the Brush collection by Mr. E. Schernikow. The analysis showed a total of 1.48 per cent of alkali oxides, a smaller amount than had been anticipated and, further, gave no test for the presence of caesium. As the specimen analyzed showed no crystal faces it was impossible to cut an orientated prism from it by means of which the two indices of refraction could be determined. A prism was, however, cut at random from a fragment of the material and the value of the index for the ordinary ray obtained. There was in the Brush collection a small crystal group of faintly pink beryl from the neighboring

* Bull. Soc. Min., xxxi, 218, 1908. † This Journal, xxviii, 25, 1884.

‡ Ibid, xxxvi, 317, 1888. § Dana's System of Mineralogy, 6th ed., p. 407.

|| This Journal, xxii, 22, 1906.

locality of Pala and, thinking, that from this specimen both indices might be determined, an orientated prism was cut from it and measurements of the two indices made. The values of the indices for the ordinary rays as determined from the two prisms were, however, quite different, that of the Pala beryl being the higher. This suggested that the two specimens differed in the amount of the alkali oxides which they contained and this was proven by sacrificing enough of the crystal to permit the making of a determination of the alkalies present. The Pala beryl was found to contain 3.77 per cent of alkali oxides of which over half of a per cent proved to be caesium oxide.

The rose-colored beryl from Madagascar contained still more alkalies, 4.98 per cent in all, 1.60 per cent of which was caesium oxide. The material analyzed showed no crystal faces and the prism for the measurement of the indices of refraction, also, had to be cut at random. It happened, however, that it must have been cut with its edge very closely parallel to the direction of the optical axis for the birefringence shown was quite what would have been expected through the study of the various other results. In order to prove the orientation of the prism, a section was cut from it at right angles to its faces and, in convergent light, this section showed an uniaxial interference figure nearly symmetrically centered in the field of conoscope. So the

	I Mesa Grande Analyst, Ford	II Willimantic Analyst, Penfield	III Pala Analyst, Ford	IV Madagascar Analyst, Ford	V Hebron Analyst, Wells
SiO ₂ ---	64.98	65.72	undet.	62.79	62.44
Al ₂ O ₃ --	17.86	18.40	undet.	17.73	17.74
Fe ₂ O ₃ --	----	----	----	----	0.40
FeO ---	----	0.26	----	----	----
MnO ---	----	0.12	----	trace	----
BeO ---	13.42	13.08	undet.	11.43	11.36
Cs ₂ O ---	----	----	0.57	1.70	3.60
K ₂ O ---	0.18	0.12	0.28	----	----
Na ₂ O --	0.84	0.75	1.59	1.60	1.13
Li ₂ O ---	0.46	0.28	1.33	1.68	1.60
Ign ----	2.16	2.06	undet.	2.65	2.03
Total ..	99.90	100.79	----	99.58	100.30
Total alkalies	1.48	1.15	3.77	4.98	6.33
Specific gravity	2.714	2.73	2.785	2.79	2.80
ω =	1.58157	1.58455	1.59239	1.59500	1.59824
ϵ =	undet.	1.57835	1.58488	(1.58691)*	1.59014
$\omega - \epsilon =$		.00620	.00751	(.00809)*	.00810

* Approximate.

values of the index for the extraordinary ray and the birefringence, as determined from the prism, while not exactly correct, must be very nearly so and consequently they have been quoted, the figures being enclosed in each case in a parenthesis.

Above are given the various analyses with the corresponding determinations of the indices of refraction and specific gravity. The indices of refraction were all measured in sodium light.

From the consideration of the above table it is quite clear that the replacement of beryllium oxide in beryl by the various alkali oxides raises both the specific gravity and the values for the indices of refraction in the mineral. There is also shown an increase in the amount of birefringence as the percentage of the alkali oxides rises. The relationship that exists in minerals between their composition and their optical constants is at best exceedingly complicated. And in the case of beryl where one oxide (BeO) is replaced in varying amounts by four other oxides (Li_2O , Na_2O , K_2O , and Cs_2O), possessing widely differing molecular weights, it is impossible in our present state of knowledge to derive any law that shall accurately coördinate the chemical and optical factors. It is, however, a recognized fact that, in general, where a mineral varies in its composition by the isomorphous replacement of one element or oxide by another, the values of the indices of refraction and the specific gravity are raised, when the replacing element or oxide has a higher atomic or molecular weight than the one replaced and vice versa. The results of the present investigation of beryl are fully in accord with this principle. The effect of such variation in composition upon the birefringence of the mineral is, however, apparently not necessarily a corresponding one, although, in the case of beryl, it also rises in amount with increase in the values of the indices of refraction.

An interesting fact might be noticed in this connection. Ordinarily because of their comparative low molecular weights (excepting in the case of the rare oxide of cæsium) the introduction of alkali oxides into a mineral serves to lower its indices of refraction and birefringence. The opposite is true in beryl and apparently so because the oxide replaced, BeO , has a lower molecular weight than any of the alkali oxides, the respective values being as follows: BeO , 25.1; Li_2O , 30.06; Na_2O , 62.10; K_2O , 94.30; Cs_2O , 281.76. It could, therefore, be reasonably assumed that the introduction of any of the alkalies would cause the rise of the values for the refractive indices, but it is probable, however, that the presence of cæsium oxide with its high molecular weight would have the predominating influence.

Laboratory of Mineralogy,
Sheffield Scientific School, Yale University,
New Haven, Conn., June, 1910.

ART. X.—*The Correlation of the Guadalupian and the Kansas Sections**; by J. W. BEEDE.†

Introduction.—The appearance of the “Guadalupian Fauna”‡ again brought into prominence the question concerning the age of the rocks of Kansas and Oklahoma that have usually been referred to the lower Permian. The writer thought it quite necessary to make a trip to the Guadalupe region last season in order to determine anew the stratigraphic relationship and, if possible, to determine the paleontologic interrelations of the red beds and the Guadalupian limestones. These red beds are common to the Texas and Kansas regions, and their age and relationships are known. If the relative position of these beds to the Guadalupian deposits could be established, then the correlation of the deposits with those of Kansas could readily be made. The outcrop of the Guadalupian strata were therefore studied during the summer of 1909, and with the assistance of Mr. Hal P. Bybee during the earlier part of the season.

Stratigraphy.

Our visit to the region last summer was for the purpose of reviewing the stratigraphic relationship and determining whether the Pecos valley red beds actually occupied a higher position than the Guadalupian limestones and, if possible, to secure fossils from them which would demonstrate their age. Only the general itinerary and more important observations will be mentioned here.

After a brief survey of the region lying east of the Davis mountains, from Phantom Lake to Kent, and San Martine, Texas, we traveled west and north from Toyah over the Cretaceous red beds, and along the eastern outcrop of the Delaware mountain formation to Guadalupe Point. Here the upper part of the type section of the Guadalupian series was studied and collections made. Then at Carlsbad, New Mexico, the Pecos valley red beds with the subjacent limestones and sandstone were seen, with broad, low anticlines of the upper Guadalupian limestone protruding through them. Farther west the gypsum deposits of the red beds appeared in the synclines and on the sides of the anticlines. East of Queen the upper-Guadalupian limestones rise from beneath the gypsum beds and form the mass of the Guadalupe mountains of this region, some thirty miles north of Guadalupe Point. A trip south through the

* Read before the Paleontological Society of America, Dec., 1909.

† By permission of the State Geologist of Kansas.

‡ Girty, U. S. Geol. Surv., Prof. Paper 58, 1908 [1909]. See also Richardson's paper in this Journal, April, 1910, pp. 325-337.

mountains to the Texas line gave assurance of the stratigraphic position of the uppermost beds shown at Carlsbad and at Queen.

Near Carlsbad were studied a locality thirteen miles west of town (five miles west of McKittrick spring), and another at the mouth of Dark canyon. The beds here consist of thin limestones and covered slopes apparently composed of soft sandstones or clays. Shales are visible at McKittrick spring. These rocks overlie the massive upper Guadalupean limestone. Numerous pieces of yellowish sandstone were seen on the north side of Pine canyon, near Guadalupe Point on the top of the mountain, though none were seen in place. Near the head of Dog canyon and about Queen the sandstones are in place. The stratigraphy is well shown in Sitting Bull canyon just below Queen. The physical character of the Capitan in the northern extension of the Guadalupe changes rapidly. In Pine canyon itself it seems to be composed to some extent of large lenticular masses, while in Sitting Bull canyon rocks nearly 500 feet below the summits of the mountain show cross-bedding on a magnificent scale. Sometimes the lithological character of the beds varies very rapidly. North of the region of Guadalupe Point, the purer limestones appear to be replaced by those of dolomitic appearance, and with this change the Capitan fauna ceases, being nearly unknown north of the Texas line.

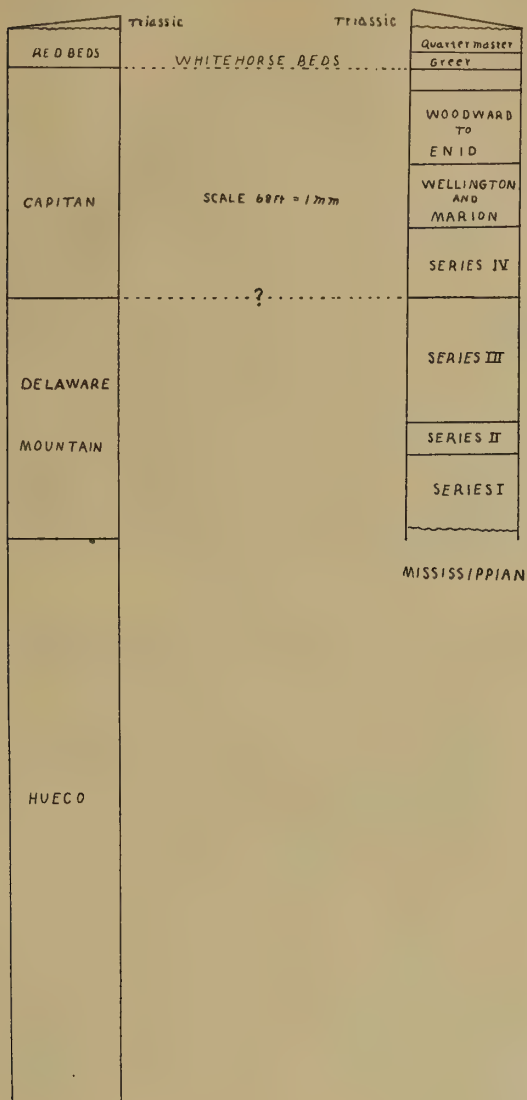
In the vicinity of Carlsbad the general stratigraphic relations of the red beds and underlying limestones and sandstones are well shown. A section of the rocks at the locality west of the McKittrick spring is as follows:

10. First terrace of thin-bedded limestone resting on Guadalupean limestone	70 ft.
9. Main cliff of limestone	70 "
8. Soft arenaceous limestone	5 "
7. Limestone lying below main cliff	12 "
6. Limestone, pisolitic in the upper part	5 "
5. Limestone, hard, oolitic in places	15 "
4. Hard limestone, locally oolitic	5 "
3. Limestone, dark below, lighter above	50 "
2. Dense or porous limestone with much travertine	4 "
1. Fine-grained crystalline homogeneous limestone	5 "
Total	241 "

Fossils were taken from blocks of massive limestone, probably from near the base of the section. Near Carlsbad these upper rocks (number 10 of the section), and other strata not exposed, appear to be two or three hundred feet thick and plunge with gentle dip beneath the red beds of the Pecos valley. The red beds of this region are composed of sand-

FIG. 1.

GUADALUPE MTS STAKED PLAINS PANHANDLE-KANSAS



stones, clays, and bands of limestone separating gypsum beds. The western extension of the beds is nearly void of red sand-

stones and clays and only thin bands of limestone occur with just sufficient red material to suggest their relationship to the rocks a few miles farther east, where the clays and sands are more abundant. However, about ten miles northwest of San Martine is an outcrop of a hundred feet or so of red sandstone which may possibly be Triassic in age.

East of Carlsbad, near the rim of the Staked Plains, red sandstone overlies the gypsiferous beds. These beds were reported to me by Professor E. O. Wooton, of the Agricultural college at Las Cruces, who made a trip up to the Plains at the time of my visit. They are the Triassic beds of Drake.*

The gypsiferous beds are excellently exposed in the high bluff six miles south of Lakewood, south of the South Fork of Seven Rivers and west of the Pecos river. In the northern scarp of the hills, near the eastern end, the gypsum is nearly 300 feet thick as measured by the barometer. The layers are separated by thin bands of limestone. Red materials appear on the eastern and western extension of these hills near their base. There is a limestone above the gypsum beds varying from ten to seventeen feet in thickness, but which is much thinner a mile or two farther west in the same hills. About ten feet below the crest of the escarpment and a little west of its eastern end, fossils were found, some of which are like those occurring in the Quartermaster beds in the Texas Panhandle.

On the east of the Pecos river two miles southeast of the mouth of the South Fork of the Seven Rivers, Fisher finds the following section:†

Massive gray limestone	35 ft.
Gypsum and red sandstone in alternating layers with occasional limestone ledge.....	50 "
Gypsum with thin-bedded, porous limestone, and red sandstone arranged alternately, the gypsum predominating	150 "
Gypsum with thin layers of gray limestone.....	50 "
Total	285 "

This section exhibits the normal red beds conditions east of the Pecos river and should be compared with the others from east of the river given on the same page. Cummins has compared the lithologic character of these beds with the gypsiferous upper red beds east of the Staked Plains, as well as demonstrated their stratigraphic continuity.‡ For the sake of illus-

* Geol. Surv. Tex., Third Ann. Rep., p. 246, 1892.

† U. S. Geol. Surv., Water Supply Paper 158, page 7, 1906.

‡ Geol. Surv. Tex., Third Ann. Rep., pp. 201-223, 1892.

trating the similarity the following section taken at Kiowa peak, Stonewall County, Texas,* is given :

1. Gypsum and clay	60 ft.
2. Red clay	20 "
3. Gypsum	20 "
4. Red clay	35 "
5. Gypsum	15 "
6. Gypsum, alabaster	4 "
Total	154 "

In this section the more minute details are omitted, and some thin limestones containing fossils are not given. It is doubtful if the whole thickness of the gypsum-bearing beds is seen since at the exposure the top of the hill is capped with massive gypsum. However, the succession of gypsum lentils, red clay and red sandstone is similar to that of the west side of the Pecos valley, as shown in Fisher's sections. Along much of their outcrop through the Panhandle, Oklahoma, and southward, the Greer formation, or the gypsiferous beds of the upper red beds, are overlain by a rather extensive layer of dolomite. It is found at Dozier, Texas, southwestern Oklahoma, and at Quanah, Texas. There is a similar covering of dolomite in many places in the western Pecos valley region.

Paleontology.

Since the stratigraphic evidence regarding the identity of the Pecos valley and the upper red beds east of the Staked Plains is so complete, it now remains to examine the meager paleontologic data at hand.

The fauna of the Whitehorse and Quartermaster beds has been described and its character noted.† The most common fossils of these beds are the pelecypods referred to the genus *Cyrtodontarca*. Indeed, scarcely a fragment of the fossiliferous stone can be picked up in which they are not abundant (I refer to the larger forms). These fossils are not so plentiful in any other horizon in this country so far as I am aware, and they may be considered the characteristic fossils of these beds. The Whitehorse and Quartermaster beds contain nearly forty species of fossils. The dolomites between these beds contain abundant *Schizodus* and *Pleurophorus* shells.

The fossils of the Pecos valley region are very rare so far as our present knowledge goes. Fisher found some in the lime-

* Cummins, Geology of N. W. Tex., Geol. Surv. Tex., Sec. Ann. Rep., p. 407, 1891.

† Beede, Invertebrate Paleontology of the Upper Permian Red Beds of Oklahoma and Panhandle of Texas, Kans. Univ. Sci., Bull. iv, pp. 115-168, 1907.

stone beneath the gypsum beds northwest of Roswell. He states that "Fossils are not abundant in the formation, but in one locality northwest of Roswell a number were collected, which consisted mainly of *Schizodus* and *Pleurophorus*, preserved as casts. According to Dr. Girty, the fauna and lithology of these specimens suggested the latest Carboniferous beds or Permian of the Mississippi valley in Texas." *

This correlation is in accord with the stratigraphic relationship of the beds, though Girty, in a later paper, discredits the evidence of *Pleurophorus*.

So far as I am aware this is the only record of fossils admitting of reasonable determination being found in the Permian red beds of the Pecos valley. At the locality south of Lake-wood, previously described, in the limestone capping the gypsum escarpment at a horizon probably 300 feet or more above the horizon of Fisher's specimens, fossils of some five or six species were found. They consist of *Cyrtodontarca? parallellidentata?* † C.?.sp., another pelecypod, the cast of an ostracod, and some minute gastropods from one to three millimeters in length badly preserved as molds. The *Cyrtodontarcæ* appear, though poorly preserved, to be specifically identical with one of the species from the Whitehorse and Quartermaster beds of Oklahoma and the Panhandle of Texas. Like them, these shells are by far the most abundant fossils in the collection.

At the locality west of Carlsbad, already described, in what seems to be the top of the Guadalupian limestone, specimens of *Naticella transversa*, formerly known only from the Quartermaster beds, and a *Pleurophorus* common to both the Whitehorse and Quartermaster formations, together with a few other poorly preserved specimens, were found. This occurrence indicates an earlier appearance of some of the Quartermaster forms in New Mexico than farther northeast.

These faunas of the Pecos valley red beds, limited as they are, seem to show nearly as intimate a relationship to those of the upper red beds east of the Staked Plains as does the stratigraphy of the deposits in which they occur. In short, there can be little doubt of the identity of the Pecos valley red beds with the Greer and adjacent formations of Oklahoma and western Texas.

After the Pecos valley and Guadalupe work had been completed, the writer and Dr. G. B. Richardson of the federal Survey, who had completed a similar reconnaissance in the Pecos valley and Guadalupe mountains and the region to the northwest, met at Carlsbad and compared results. His results are now published in the April number of this Journal.

* Fisher, loc. cit., pp. 7, 8.

† Identical with a Quartermaster form doubtfully referred to this genus.

General Correlations.

If the conclusions reached above are correct it leads at once to the correlation of the Kansas and Guadalupian sections. If we use the Whitehorse sandstone, probably the equivalent of the beds in contact with the Guadalupian limestone near Carlsbad, as a common basis of correlation of the two sections, we attain the result shown in the accompanying diagram.

FIG. 2.



FIG. 2. Gypsum bluff six miles south of Lakewood, New Mexico. Fossils from near top of bluff just below the dark spot in the center of picture.

Disregarding their actual faunal relationships and comparing them as to their thickness, the strata of the two sections compare as follows, the figures of the Guadalupian rocks being approximations:

In southern New Mexico we have some 4,500 feet of the Guadalupian series composed of 2,100 feet of Capitan and overlying limestones and 2,400 feet of the Delaware Mountain formation composed of limestones and sandstones overlying 5,000 feet of Hueco limestones. Beginning at the same horizon in Kansas, we have the remainder of the red beds, the lighter Permian and the Pennsylvanian, aggregating about 4,500 feet of strata, composed of limestone shales and sandstone. So far as mere thickness is concerned it leaves the base of the Delaware Mountain formation about on the level with the base of the Cherokee shales (as exhibited in Kansas). The horizon of the base of the Delaware Mountain formation in the Kansas section interpreted upon its fauna, or actual time equivalency,

may be a very different matter. The base of the Capitan falls near the bottom of the Elmdale formation stratigraphically, which is, probably, not far from its correct faunal correlation as well. The paleontological comparisons are yet to be worked out. The unconformity above the Capitan limestone and locally even on the Delaware Mountain formation, the Capitan having been carried away, is not taken into account in making these comparisons.* It is probable that it diminishes rapidly to the northward, where it is of less consequence.

One of the most interesting features of the Guadalupian fauna is its isolation. As has been stated by Girty, the fauna is a unique one, and, as a unit, is now known from no other part of the western hemisphere. At first thought it seems peculiar that more of its members were not distributed over the adjacent regions where contemporaneous strata occur. Their absence in such rocks has been a serious difficulty in any attempt to correlate them with other American faunas.

In the first place, the lower red beds lying to the eastward, with which the Guadalupian limestones are probably contemporaneous, are believed by some to be to a considerable extent of subaërial origin, while the temporary seas that occupied portions of it from time to time were too concentrated in salt content for normal marine faunas. So far as my collecting in the typical Capitan limestone goes, the fossils were abundant only in the purer limestones, and were very rare or wanting in what appeared to be the dolomitic portions of it. These limestones occur in the Apache Mountains and at Guadalupe Point, but appear to be wanting, as does the fauna, north of the Texas line; the only exceptions noted were *Fusulina elongata*, and one or two other species in Dog canyon and Sitting Bull canyon. From this it will be seen that the fauna was closed off on the north by untoward conditions and on the east by the red bed sedimentation, which constituted a barrier. No other barrier is known.

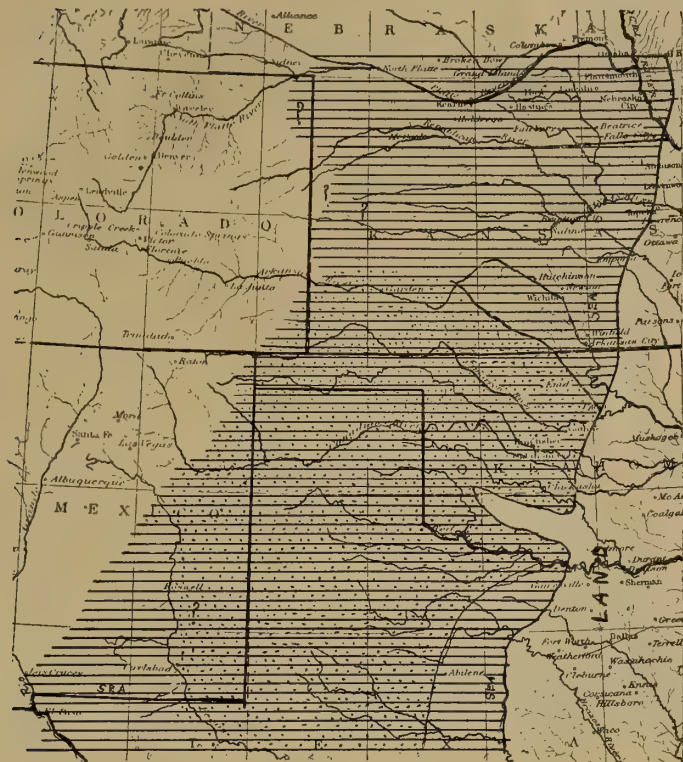
Two other considerations must be taken into account. First, that the Permian facies of this fauna may be an abnormally early precursor of the Permian faunas developed in an isolated basin.† Such an occurrence of Permian forms is known in Kansas well down in deposits of Pennsylvanian age. However, the variety and richness of the Guadalupian fauna, which possesses such a young appearance, seem to me to argue against this hypothesis. Second, the other possibility is that the fauna is no older than it appears and that it developed normally

* Richardson, Univ. Min. Surv. Tex., Bull. 9, pp. 43-44, 1904.

† The idea of local isolation of the fauna was first suggested to me by David White and later, at the meeting of the Paleontological Society, by J. M. Clarke.

with little outside connection, as did the Kansas Permian fauna. The same features as before would have controlled its isolation. Much of the red beds being almost a land surface a considerable part of the time—if we accept the subaërial origin of a large part of the deposits—aggradation may have but slightly overbalanced degradation and they may have accumulated

FIG. 3.



slowly for that class of sediments. Thus, though disturbances raised the southern part of the Guadalupe limestones above sea level and permitted their partial removal and the subsequent deposition of the upper red beds upon the eroded surface, the fauna may well have been an early Permian fauna. Until further data are at hand I am much inclined to this latter hypothesis. The fact that several hundred feet of the Kansas Permian deposits grade off into typical red beds in a very short distance in Oklahoma is suggestive of possible conditions east of the Guadalupe. If such were the case, we

would expect the Guadalupian faunas to cease as abruptly upon the strata changing to the red beds as the Kansas faunas do upon entering the Oklahoma red beds.

At the same time, owing to the very nature of the origin of the red beds, their extreme southwestern part may have been deposited slightly later than the main mass farther to the north and east. However, this is regarded more in the nature of a possibility than a probability.

The accompanying map (fig. 3) indicates the probable relationship of the marine areas during Council Grove-Chase and Guadalupian time in the immediate area under consideration. No attempt is made to show the full extent of deposits laid down at this time. The full lines indicate marine conditions and the lines alternating with stippled ones continental-marine deposition. The extent to which the two factors contributed to the formation of the red beds is at present unknown. The area of marine conditions in Central Texas is to represent the Albany sea.

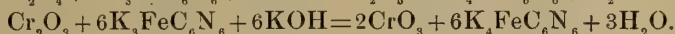
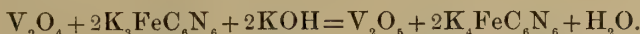
Bloomington, Indiana.

ART. XI.—*The Application of Potassium Ferricyanide in Alkaline Solution to the Estimation of Vanadium and Chromium*; by HOWARD E. PALMER.

[Contributions from the Kent Chemical Laboratory of Yale Univ.—ccxiii.]

IN previous papers from this laboratory methods for the estimation of cerium in the presence of the other rare earths,* for the estimation of thallium,† and for the estimation of arsenic, antimony, and tin‡ have been described, based on the oxidizing action of potassium ferricyanide in alkaline solution, and reoxidation by permanganate of the resulting ferrocyanide in acid solution.

The present paper deals with the application of these reactions to the estimation of vanadium and chromium. The reactions involved may be represented by the following equations:

*Estimation of Vanadium.*

A solution of ammonium vanadate was made up by dissolving pure ammonium vanadate in water, and standardized by evaporating definite portions in a platinum crucible and weighing as V_2O_5 after ignition.

Through definite portions of the standardized solution of ammonium vanadate, made slightly acid with hydrochloric acid, a current of sulphur dioxide was passed until the clear blue color indicated complete reduction of the vanadium to the condition of V_2O_4 . The solution was then boiled in a current of carbon dioxide until the last traces of sulphur dioxide were removed. To the cooled solution a solution of potassium ferricyanide containing at least ten times as much ferricyanide as is theoretically necessary for the oxidation, and a solution containing about 6 grams of potassium hydroxide were added, having the solutions of ferricyanide and potassium hydroxide sufficiently concentrated so that the total volume of the solution was about 100 or 125 cubic centimeters. At least the amounts of ferricyanide and potassium hydroxide stated were found to be necessary to ensure complete oxidation of the vanadium with the concentration employed, and if the solution was more dilute, more ferricyanide was required. It then became necessary to remove the vanadium before acidification and titration with

* This Journal, xxvi, 83. † Ibid., xxvii, 379. ‡ Ibid., xxix, 399.

permanganate, as, if not removed, it would form a precipitate with the ferrocyanide. The removal of the vanadium was effected by means of a solution of barium hydroxide, which completely precipitated the vanadium as barium vanadate; this precipitate, after settling, was filtered off on an asbestos felt, and the filtrate and washings were acidified with hydrochloric acid and titrated with permanganate. Titration in sulphuric acid solution was unsatisfactory on account of the difficulty in noting the end point in the presence of the precipitate of barium sulphate which was formed by the action of the sulphuric acid on the excess of the barium salt, and it has been found, in connection with the previous work, that, unlike the case of ferrous salts, ferrocyanide may safely be titrated by permanganate in the cold in dilute hydrochloric acid solution. The results of the determinations are recorded in Table I.

TABLE I.

	V ₂ O ₅ taken grm.	K ₃ FeC ₆ N ₆ used grm.	KOH used grm.	V ₂ O ₅ found grm.	Error grm.
(1)	0.0960	4	6	0.0959	−0.0001
(2)	0.0960	4	6	0.0954	−0.0006
(3)	0.0960	4	6	0.0956	−0.0004
(4)	0.0960	4	6	0.0962	+0.0002
(5)	0.0960	4	6	0.0956	−0.0004
(6)	0.0960	4	6	0.0959	−0.0001
(7)	0.0960	4	6	0.0961	+0.0001
(8)	0.0960	4	6	0.0961	+0.0001
(9)	0.0960	4	6	0.0960	±0.0000
(10)	0.0960	4	6	0.0961	+0.0001

Estimation of Chromium.

As Bollenbach and Luchmann have recently shown,* chromium may be quantitatively oxidized from the condition of Cr₂O₃ to the condition of CrO₃ by potassium ferricyanide in alkaline solution, and a measure of the oxidation obtained by titrating with permanganate the ferrocyanide formed.

According to their method an excess of at least 4 to 6 times the theoretical amount of potassium ferricyanide and 40 to 50 cubic centimeters of a 2-normal solution of sodium hydroxide were added to the solution containing the chromium to insure complete oxidation of the chromium. The oxidized chromium was removed by precipitation as barium chromate by means of barium hydroxide solution, and filtration. The filtrate was then acidified with hydrochloric acid and titrated with permanganate according to Bollenbach's modification of De Haen's method,† designed to overcome the difficulty involved in

* Zeitschr. für anorg. Chem., ix, 446.

† Zeitschr. für anal. Chem., xlvii, 687.

obtaining an exact end point in the titration of large amounts of ferrocyanide, owing to the formation of a precipitate of $K_2MnFeC_6N_6$ during the titration, as was first pointed out by Grützner.* This modification consisted in adding an excess of permanganate to the solution and, after the precipitate had cleared up, titrating back the excess of permanganate with $\frac{n}{20}$

potassium ferrocyanide in the presence of a trace of a ferric salt, the formation of a permanent green coloration due to the ferric ferrocyanide indicating the end point.

In experiments carried on in confirmation of this method a solution of potassium chromate was used, whose standard had been determined by precipitating definite portions as mercurous chromate and weighing as Cr_2O_3 after ignition; and also by precipitating as chromium hydroxide by ammonia, after reduction with hydrochloric acid and alcohol, and weighing as Cr_2O_3 .

The determinations were made as follows: Portions of the standardized solution were made slightly acid with hydrochloric acid, and a current of sulphur dioxide was passed through the solution until the clear green color indicated complete reduction of the chromium to the condition of Cr_2O_3 . The sulphur dioxide was then expelled by boiling in a current of carbon dioxide. To the cooled solution potassium ferricyanide and potassium hydroxide were added in solution and the procedure given by Bollenbach and Luchmann, as outlined above, was followed.

However, using the amounts of ferricyanide and potassium hydroxide given by Bollenbach and Luchmann as sufficient to completely oxidize the chromium, the low results of Table II were obtained, indicating that the oxidation of the chromium was incomplete; but by using about 15 times the theoretical amount of potassium ferricyanide and a rather strong solution of potassium hydroxide, with the total volume of the solution about 100 or 125 cubic centimeters, as in the experiments recorded in Table III, results were obtained which were in accordance with the theoretical.

As in the previous work, a correction had to be applied to the determinations for the amount of permanganate taken up by the ferricyanide alone.

TABLE II.

	CrO_3 taken gram.	$K_2FeC_6N_6$ used gram.	KOH used gram.	CrO_3 found gram.	Error gram.
(1)	0.1010	6	12	0.0979	-0.0031
(2)	0.1010	8	16	0.0981	-0.0029
(3)	0.1010	8	16	0.0989	-0.0021
(4)	0.1010	8	12	0.0997	-0.0013

* Chem. Zentralblatt, 1902, i, 500.

TABLE III.

	CrO ₃ taken gram.	K ₃ FeC ₆ N ₆ used gram.	KOH used gram.	CrO ₃ found gram.	Error gram.
(1)	0.1010	16	15	0.1016	+0.0006
(2)	0.1010	16	15	0.1014	+0.0004
(3)	0.1010	16	15	0.1013	+0.0003
(4)	0.0505	16	15	0.1514	+0.0009
(5)	0.0505	16	15	0.0506	+0.0001

Estimation of Vanadium and Chromium when present together.

For the estimation of both vanadium and chromium when present together, the following method was worked out: The solution containing the vanadium and chromium, both in the higher condition of oxidation, was divided into two portions. Into one portion of the solution, made slightly acid with hydrochloric acid, sulphur dioxide was passed until the reduction of the vanadium and the chromium was complete; the solution was then boiled in a current of carbon oxide until the last traces of sulphur dioxide were expelled. To the cooled solution a sufficient excess of potassium ferricyanide and potassium hydroxide were added in solution. By this process the chromium was oxidized from the condition of Cr₂O₃ to the condition of CrO₃ and the vanadium from the condition of V₂O₄ to the condition of V₂O₅. After allowing the solution to stand a few minutes, a solution of barium hydroxide was added to complete precipitation. The combined precipitates of barium chromate and barium vanadate were filtered off on asbestos and thoroughly washed; the filtrate was made acid with dilute hydrochloric acid and titrated with a known amount of permanganate in excess, and the excess titrated with $\frac{n}{20}$ potassium ferrocyanide, according to the method given above.

In the other portion of the solution the vanadium was determined as follows: The solution, about 100 cubic centimeters in volume, was made acid with from 10 to 15 cubic centimeters of glacial acetic acid, and hydrogen peroxide was added. The solution was then heated to boiling and boiled for a few minutes; by this process the perchromic acid and the pervanadic acid, which were first formed in the cold, were decomposed, the chromium being reduced to the condition of Cr₂O₃, while the vanadium remained in the condition of V₂O₅. The solution was diluted somewhat, and a solution of lead acetate was added to complete precipitation of the lead vanadate; the chromium, being in the condition of Cr₂O₃, was not precipitated. The solution was stirred vigorously to coagulate the precipitate, and

was heated to boiling, which had the effect of making the precipitate more compact. The precipitate was filtered off on asbestos, washed thoroughly, and dissolved in potassium hydroxide. The solution was made strongly acid with sulphuric acid, whereby the lead was precipitated as the sulphate, while the vanadic acid remained in solution. A current of sulphur dioxide was then passed through the solution until the blue color indicated complete reduction of the vanadium to the tetroxide condition; and the sulphur dioxide was expelled by boiling in a current of carbon dioxide. The warm solution was then titrated with permanganate until the first permanent pink color appeared; and this could be easily recognized in the presence of the white precipitate of lead sulphate.

This titration gave a measure of the amount of vanadium present; and by subtracting the number of cubic centimeters of permanganate used in this titration from the number of cubic centimeters used in the preceding titration, the number of cubic centimeters corresponding to the oxidation of the chromium from Cr_2O_3 to CrO_3 was obtained.

The results of the determinations are given in Table IV.

TABLE IV.

	V_2O_5 taken grm.	CrO_3 taken grm.	V_2O_5 found grm.	Error grm.	CrO_3 found grm.	Error grm.
(1)	0.1139	0.1010	0.1134	-0.0005	0.1010	± 0.0000
(2)	0.1139	0.1010	0.1139	± 0.0000	0.1017	+0.0007
(3)	0.1139	0.1010	0.1134	-0.0000	0.1019	+0.0009
(4)	0.1139	0.1010	0.1142	+0.0003	0.1019	+0.0009
(5)	0.1139	0.1010	0.1131	-0.0008	0.1015	+0.0005
(6)	0.1139	0.1010	0.1134	-0.0005	0.1016	+0.0006
(7)	0.1139	0.0505	0.1139	± 0.0000	0.0507	+0.0002
(8)	0.1139	0.0505	0.1134	-0.0005	0.0507	+0.0002
(9)	0.0569	0.0505	0.0565	-0.0004	0.0505	± 0.0000
(10)	0.0569	0.0505	0.0563	-0.0006	0.0508	+0.0003

ART. XII.—*Ludwigite from Montana*; by WALDEMAR T. SCHALLER.*Occurrence and Association.*

THE ludwigite here described was collected at Philipsburg, Montana, by Mr. Donald F. MacDonald and sent to the chemical laboratory of the Survey for determination by Mr. F. C. Calkins. It is stated to occur in metamorphosed limestone with large bodies of magnetite. An examination of a thin section showed that a member of the olivine group was sprinkled throughout the ludwigite and in addition a minute amount of a carbonate and a secondary fibrous mineral was present.

The ludwigite forms small spherulites composed of radiating fibers of a very dark green or nearly black color. In its physical properties it resembles the original ludwigite from Hungary. Under the microscope with high magnification the fibers extinguish parallel and show a strong pleochroism, parallel to the elongation a sea-green, normal thereto a chestnut-brown with stronger absorption in the brown than in the green. The refractive index is much higher than 1.67. The olivine mineral has a mean refractive index of about 1.66 and cleavage sections, parallel to $b \{010\}$, showing α and β have refractive indices lying between 1.65 and 1.66. The mineral must therefore be very low in ferrous iron and is referred to forsterite. As no calcium was noted in the analysis, the carbonate is either magnesite or siderite.

Analysis.

The sample free from magnetite but containing a small quantity of forsterite and minute amounts of the colorless fibrous mineral and the carbonate, gave on analysis the following results, the figures in the last column showing the values with the forsterite and carbonate deducted and the analysis recalculated to 100 per cent.

The ferrous iron was determined by a modification of Pratt's method,* using finely ground material. Some experiments conducted by Dr. Hillebrand on samples of this mineral showed that the oxidizing effect of grinding on the ferrous iron was slight. The first value for alumina (1.98 per cent) was obtained as the difference between the gravimetric determination of R_2O_3 and the subsequent volumetric titration

* Hillebrand, W. F. The Analysis of Silicate and Carbonate Rocks, Bull. 305, U. S. Geol. Survey, 1907, p. 138.

Analysis of Ludwigite from Montana.

	Analysis of ludwigite mixed with forsterite and carbonate.			Analysis of ludwigite.	
	1	2	3	Average	
FeO -----	6.12	5.53	5.74	5.79	7.27
MgO -----	39.09	38.60	39.42	39.04	33.78
Total iron ----	36.33	36.01	----	----	----
Fe ₂ O ₃ -----	-----	-----	-----	29.73	37.37
SiO ₂ -----	8.97	8.74	8.85	8.85	-----
Al ₂ O ₃ -----	1.98	1.64	-----	1.81	2.27
H ₂ O+ -----	.97	-----	-----	.97	1.24
H ₂ O- -----	.91	.95	.85	.90	1.13
CO ₂ -----	.28	.43	-----	.36	-----
B ₂ O ₃ -----	13.48	-----	-----	13.48	16.94
				100.93	100.00

of the iron with permanganate solution. The iron and aluminum chloride solution was repeatedly evaporated with methyl alcohol to expel all the boric acid. The second value (1.64 per cent) was determined by precipitating the alumina by phenylhydrazine, as described by Allen.* As the two determinations agree fairly well, the presence of a small amount of alumina in the sample seems well confirmed. The higher result of the first case is probably due to the retention of a small amount of boric acid. Whether the alumina belongs to the ludwigite or to one of the accompanying minerals is difficult to decide, but it has here been included in the borate. The boric acid content has also been determined by Wherry and Chapin,† who give as the average of their results 12.82 per cent B₂O₃, a value slightly lower than the one here given.

The water content, though small, is still of sufficient importance to merit consideration. While no definite conclusion has been reached, it is believed that most, if not all, of the water is really unessential to the mineral. The determinations were made on the finely ground material and considerable water was thereby unquestionably taken up by the mineral.‡ As some water may also have been furnished by the secondary fibrous material, it therefore seems justifiable to conclude that a good part, if not all, of the water reported in the analysis is extraneous. It has been entirely omitted in the consideration of the ratios deduced from the analyses.

* Journ. Amer. Chem. Soc., vol. xxv, p. 421, 1903. See also Bull. 305, U. S. Geol. Survey, p. 95.

† Determination of Boric Acid in Insoluble Silicates, E. T. Wherry and W. H. Chapin. Journ. Amer. Chem. Soc., vol. xxx, p. 1691, 1908.

‡ For data on this point, see this Journal, vol. xxv, p. 328, 1908.

Discussion of Formula.

From the figures of the average analysis, the ratios were calculated and found to be as follows :

Ratios of ludwigite analysis.

MgO	9760	-----	}	7532	4.00	{	3.57 MgO
FeO	804	-----					
Fe ₂ O ₃	1858	[Less 1475 Mg ₃ SiO ₄	}	2035	1.08	{	.43 FeO
Al ₂ O ₃	177	and 82 MgCO ₃]					
SiO ₂	1475						
CO ₂	82						
B ₂ O ₃	1926	-----		1926	1.02		

The ratios agree well with the formula generally given for ludwigite, $4\text{RO} \cdot \text{Fe}_2\text{O}_3 \cdot \text{B}_2\text{O}_3$. The high water content obtained by Whitfield,* on the Hungarian material, namely 3.62 per cent, is substantiated neither by the analysis of the Montana mineral, as given above, nor by the analysis of the material from Hungary, as described beyond. Yet both samples yield about a per cent of water which is at present impossible to prove foreign to the mineral and may, in time, be shown to be an essential constituent thereof. If the water given off above 107° ($\text{H}_2\text{O} +$) be considered as essential to the mineral, a formula of about the proportions $\text{RO} : \text{Fe}_2\text{O}_3 : \text{B}_2\text{O}_3 : \text{H}_2\text{O} = 16 : 4 : 4 : 1$ would result.

While the ratios agree well with the general formula of ludwigite, the amount of ferrous iron is too small (even by referring all the ferrous iron in the analysis to ludwigite and none to either the forsterite or the carbonate) for the formula $\text{FeO} \cdot \text{Fe}_2\text{O}_3 \cdot 3\text{MgO} \cdot \text{B}_2\text{O}_3$. From the data given above, the formula for the Montana ludwigite may be written $.57\text{MgO} \cdot .43\text{FeO} \cdot 3\text{MgO} \cdot \text{B}_2\text{O}_3$, showing an isomorphous mixture of a *ferrous* ferric magnesian borate with a *magnesian* ferric magnesian borate, the latter being in excess.

As has been previously shown by the analyses of Ludwig and Sipöcz and of Whitfield and confirmed by the analysis given beyond, the Hungarian mineral approximates closely to the definite formula $\text{FeO} \cdot \text{Fe}_2\text{O}_3 \cdot 3\text{MgO} \cdot \text{B}_2\text{O}_3$, though one analysis by Ludwig and Sipöcz shows a slight deficiency in the ferrous iron. The mineral from Montana, however, is very much lower in the ferrous iron and correspondingly higher in the magnesia, the ratios of $\text{B}_2\text{O}_3 : \text{Fe}_2\text{O}_3 : \text{FeO} + \text{MgO}$ remaining constant. There is here, then, sufficient evidence of the existence of magnesian ferric borate, $\text{MgO} \cdot \text{Fe}_2\text{O}_3 \cdot 3\text{MgO} \cdot \text{B}_2\text{O}_3$, free from ferrous iron, not yet found in nature in the pure state but preponderant in the Montana ludwigite, being present

* Whitfield, this Journal, vol. xxxiv, p. 284, 1887.

in isomorphous mixture with the corresponding ferrous ferric magnesian borate, to the extent of 57 per cent or over half. If some of the ferrous iron present in the sample belongs to the forsterite or the carbonate, the percentage of the magnesian borate would be still greater.

Ludwigite from Hungary.

For comparison with the above, an analysis was also made of the ludwigite from Hungary. The quantitative analysis, made on the finely radiating black mineral, is as follows:

Analysis of ludwigite from Hungary.

	1	2	3	Average
FeO -----	15.84	15.68	15.80	15.84
MgO -----	28.88	28.88	-----	28.88
Total iron as Fe ₂ O ₃ --	53.35	52.74	53.72	-----
Fe ₂ O ₃ -----	-----	-----	-----	35.67
H ₂ O- -----	.50	.52	-----	.51
H ₂ O+ -----	.78	.86	-----	.82
CO ₂ -----	.90	-----	-----	.90
Insol. -----	.32	.40	-----	.36
B ₂ O ₃ -----	[17.02]	-----	-----	[17.02]
				100.00

The ratios from the average analysis give, after deducting sufficient MgO for the CO₂ to form magnesite, the formula FeO.Fe₂O₃.3MgO.B₂O₃, as shown below.

Ratios of ludwigite analysis.

FeO -----	.220	.99
MgO -----	.702	3.06
Fe ₂ O ₃ -----	.223	1.00
B ₂ O ₃ -----	.243	1.09
CO ₂ -----	.020	-----

Summary.

The isomorphous relation of the FeO and MgO in ludwigite can be well shown by bringing together the available analyses, which also shows how closely the mineral from Hungary agrees with the calculated values for the pure ferrous-iron ferric magnesian borate. The first column gives the calculated values for FeO.Fe₂O₃.3MgO.B₂O₃, the second, third, fourth, and fifth the analyses of the Hungarian mineral and the sixth that of ludwigite from Montana.

Analyses of ludwigite.						
	1	2	3	4	5	6
	FeO.Fe ₂ O ₃ 3MgO.B ₂ O ₃	Ludwigite from Hungary analyzed by:			Ludwigite from Montana	
		Ludwig & Sipöcz	Schaller	Whitfield	Ludwig & Sipöcz	
FeO ..	17.01	17.67	15.84	15.78	12.46	7.27
MgO ..	28.61	26.91	28.88	30.57	31.69	33.78
Fe ₂ O ₃ -	37.81	39.29	37.67	35.93	39.92	37.37
Al ₂ O ₃ -	-----	-----	-----	-----	-----	2.27
B ₂ O ₃ -	16.57	15.06	[17.02]	12.04	16.09	16.94
MnO -	-----	tr.	-----	0.16	tr.	-----
H ₂ O -	-----	-----	0.51	-----	-----	1.13
H ₂ O +	-----	-----	0.82	3.62	-----	1.24
SiO ₂ -	-----	-----	0.36	-----	-----	-----
CO ₂ -	-----	-----	0.90	-----	-----	-----
	100.00	98.93	100.00	100.16	100.16	100.00

The second analysis (column 5) by Ludwig and Sipöcz shows a slight replacement of the ferrous iron by magnesia, carried out to a much larger extent in the mineral from Montana. All new occurrences of ludwigite should be carefully examined chemically, as the possibility of the existence of the ferrous-iron free magnesian borate is strongly indicated by the above analyses.

Chemical Laboratory, U. S. Geological Survey.

ART. XIII.—*Chemical and Optical Study of a Labradorite;*
by W. E. FORD and W. M. BRADLEY.

THROUGH the courtesy of Dr. George F. Kunz the Brush Mineral Collection received some time ago a suite of water-worn pebbles of a perfectly clear and almost colorless mineral which on investigation proved to be a labradorite. The locality from which the specimen came is given by a correspondent of Dr. Kunz as the Altai Mountains, in Mexico, just across the international boundary from New Mexico. The specimens offered ideal material for chemical and optical study, and as plagioclase feldspars of this composition are not very frequent in occurrence, it was thought that a brief description of the mineral would be of interest.

The analysis by Bradley gave the following results:

	I	II	Average	Molecular Ratios
SiO ₂ -----	51·27	51·21	51·24	·8483
Al ₂ O ₃ -----	30·89	30·79	30·84	·3017
CaO -----	13·52	13·65	13·59	·2422
Na ₂ O -----	3·74	3·78	3·76	·0605
K ₂ O -----	0·18	0·16	0·17	·0018
Fe ₂ O ₃ -----	0·71	0·75	0·73	----
Ign -----	0·24	0·15	0·24	----
	100·55	100·59	100·57	

	Molecular Ratios	Albite Molecule	Anorthite Molecule
SiO ₂ -----	·8483	·3738 (or 6·00)	·4745 (or 2·00)
Al ₂ O ₃ -----	·3017	·0623 (or 1·00)	·2348 (or 1·009)
Na ₂ O + K ₂ O	·0623	·0623 (or 1·00)	
CaO -----	·2422		·2422 (or 1·021)

Ratio of albite molecule to anorthite molecule, 1: 1·918.

The small amount of water is considered to be hygroscopic and the 0·7 per cent of ferric oxide is assumed to be due to small inclusions of hematite as explained in a later paragraph. On calculation the analysis gives, as is shown above, the ratio of the albite molecule to that of anorthite as 1: 1·918. This places the mineral in about the middle of the labradorite series.

The specific gravity of the material analyzed was found to be 2·718. The theoretical value for the specific gravity of a mixture corresponding to Ab₁An_{1.918} obtained by using the values of the specific gravities for the end members of the

series as given by Day and Allen,* (Albite = 2.605; Anorthite = 2.765) was found to be 2.710.

The mineral was water-clear and almost colorless, showing only in the larger pieces a faint tinge of yellow. In some cleavage fragments, when viewed perpendicular to the poorer cleavage face $b(010)$, a copper-like reflection was seen, similar to that in the sun-stone from Tvedestrand, Norway. It was evidently due to minute tabular inclusions of some iron oxide, probable hematite, which lay in planes parallel to $b(010)$. On examination under the microscope with a high-power lens these inclusions were seen to be very minute and without crystal outline, many of them possessing a curved shape similar to that of a comma. One fragment showed larger inclusions which in this case were arranged parallel to both cleavage directions. These larger inclusions were more regular in shape, being in general like very thin wafers with a circular or slightly elliptical outline and having a lens-shaped cross-section. A thin section of this specimen ground parallel to one of its cleavage surfaces showed under the microscope, first a series of nearly circular inclusions of a copper color scattered irregularly over the field and which were lying parallel to the plane of the section, and second, a series of thin, lens-shaped inclusions arranged in parallel lines, these latter being the cross sections of the inclusions lying in the cleavage plane perpendicular to the section.

Of the two cleavages, the one parallel to the base, $c(001)$, was excellent, while, as is usually the case with the feldspars near the anorthite end of the plagioclase series, the cleavage parallel to $b(010)$ was imperfect and difficult to obtain. Several measurements of the cleavage angle were made on different fragments, the two best giving the following closely agreeing angles, $85^{\circ} 49'$ and $85^{\circ} 50'$.

Sections were ground parallel to each cleavage face and the angles of extinction were measured in sodium light with the trace of the cleavage of the other face. On account of the imperfect cleavage parallel to $b(010)$, the two sections that were made parallel to this face were carefully adjusted so that in each case they made with the basal cleavage an angle having a value within a few minutes of theory. Sections parallel to $c(001)$ were easily made, but because of the imperfect nature of the cleavage parallel to $b(010)$ it was not always possible to be certain of this direction in the section. The method adopted was to find a cleavage fragment that showed both cleavages present, as proven by the measured angle between them, and then to grind the section parallel to

*The Isomorphism and Thermal Properties of the Feldspars; Carnegie Institution Publication, No. 31, p. 74, 1905.

c (001), making note of the direction of the line of cleavage of *b* (010).

The average values of a series of readings of the extinction angles of the two sections made in each case with the direction of cleavage of the other face were as follows :

	Measured	Calculated
on <i>b</i> (010) =	$-24^{\circ} 37$	$-25^{\circ} 33$
on <i>c</i> (001) =	$-12^{\circ} 13$	$-11^{\circ} 58$

In the second column are given the theoretical values of the extinction angles of the respective sections, calculated by Mallard's formula, as given by Schuster.* The agreement of the measured and calculated values is fairly satisfactory. Both sections when viewed in convergent polarized light show the emergence of an optic axis just beyond the field of the microscope.

Laboratory of Mineralogy,
Sheffield Scientific School, Yale University,
New Haven, June, 1910.

* Min. Petr. Mitth., v, 192, 1882.

ART. XIV.—*Halley's Comet*; by GEORGE F. CHAMBERS,
F.R.A.S.*

THIS brochure, extracted almost verbatim from the author's extended work, *The Story of the Comets*, published last year, is intended to meet the large demand occasioned by the return of Halley's comet for knowledge with regard to this comet and such facts regarding comets in general as are necessary to make the account of an individual comet intelligible in itself.

It contains all that needs to be known by the general reader of the past history of this comet and also of its present appearance up to the time of its perihelion passage, shortly after which this pamphlet was published.

The purpose of the present article is to present for reference in a form accessible to readers of this Journal a summary of this pamphlet, supplemented by reports of the later period of the comet's visibility sufficient to give a comprehensive view of the knowledge acquired from the latest apparition of what is generally considered to be, historically at least, the most interesting of all comets.

In anticipation of the return of the comet elaborate preparations were made by mathematical astronomers for its early discovery. The labor of preparation was much increased by the large perturbation by Jupiter soon after the perihelion of 1835. Nevertheless as early as 1864 Pontécoulant assigned a date for the next perihelion which proved to be a close approximation, and the final predictions of Cowell and Croumelyn published in January 1909 were but three days in error, the actual date of perihelion being April 19. This result was considerably closer than any obtained for the return in 1835.

The competition for the earliest discovery of the comet by photography was very keen and aroused much interest the world over. The first announcement of its appearance was made by Wolf from a plate taken September 11, 1909, at Heidelberg. Soon after it was found to have been fixed on a plate taken at Greenwich, Sept. 13, and some months later it was identified on a plate taken by Keeling at Helwân in Egypt late in August. Search had begun at Greenwich and Heidelberg as far back as the early part of 1908, while an unsuccessful search by Dr. O. J. Lee at the Yerkes Observatory in December, 1908, led him to conclude that it was not then as bright as the 17th magnitude.

The first visual observation of the comet was made at the Lick Observatory with the 36-inch reflector on October 16.

During November and December observations were numerous at various observatories, but on the whole they were neither

* Oxford, Clarendon Press. New York, Henry Froude, pp. 48.

very satisfactory in themselves nor consistent with one another. It seems altogether probable that the brightness of the comet fluctuated irregularly in a manner not dependent on its distance from the earth and sun, and this appears to the present writer to be the one fact of any special scientific interest noted concerning the comet during its entire period of visibility.

Rev. E. T. R. Phillips, at Ashstead in Surrey, observed it on ten nights between November 22 and December 29 and reported as follows:

"It has never regained the brightness of November 22, when it was quite unexpectedly about magnitude 10, but it exhibited some fluctuations in light. After being very faint at the end of November (nearly as low as magnitude 12) it revived somewhat in the early part of December, but on December 6, under excellent observing conditions, it was again as faint as magnitude 11·5 or 12. On December 8 it could just be glimpsed occasionally with 3½ inches eccentric stop and its magnitude was probably about 11. It was not seen again owing to bad weather till 18th, when it was surprisingly faint considering its greater proximity, probably below magnitude 12, and on 20th it was probably below magnitude 12·5. On 25th the moon was nearly full, and the comet invisible, but it was again observed on 28th. On that occasion it appeared about as difficult as when it was first seen at Ashstead on November 16. The estimated magnitude was 13."

During January, February and March the comet approached superior conjunction, and observations were for this reason limited and unimportant, though during January it became visible to the naked eye under favorable conditions, but not in the United States on account of its south declination.

Shortly before its perihelion passage, April 19, the comet passed behind the sun and appeared to the west of it in the early morning, rising at the earliest about 3 A. M.

Observations were now again limited by the brief period of visibility before strong twilight, the prevalence of cloudy weather and the light of the moon, which was full on April 24. During the first part of May, while it had not yet much receded from the sun and was still approaching the earth, the tail attained its greatest brightness but in length was very considerably foreshortened. For a short time near perihelion it was traced in the morning sky to a length of 140°. After passing between the earth and sun on May 19, when it was very nearly in true conjunction, the tail was displayed at a large angle to the line of sight in the evening sky, and after the full moon of May 22 at a good distance above the horizon, but by reason of its increased distance from the sun it was much diminished in brightness.

By the great majority of non-professional observers, who had been long waiting for a view, it will be remembered as it appeared around May 24 between 9 and 10 p. m., some 10° below Regulus and about of the 2d magnitude, with a tail faint but well defined, straight and easily discernible to the naked eye for a length of 25° , pointing almost directly toward the planet Jupiter, which was some 40° from the nucleus.

The curvature of the tail was considerable but was not conspicuous either before or after its perigee because the plane of the curvature was but little inclined to the line of sight. It was sufficient so that the tail was seen in the morning sky on the 20th of April, the day after the comet passed between the earth and the sun, the nucleus at the same time being in the evening sky.

It is not unlikely that this phenomenon was due to the formation of two separate tails of Bredechins types, extending on opposite sides of the earth at the same time.

In comparison with former appearances there is considerable evidence that the tail was somewhat less brilliant than heretofore, though the difference was not very remarkable nor more than was to be expected.

Considerable interest was felt in the passage of the earth through the tail, which on account of the curvature probably occurred on the 20th of April instead of the day of conjunction. Indeed, on account of the uncertainty as to the distribution of the cometic matter and the amount of curvature, it is not possible to assert positively that the earth actually passed through any portion of the tail.

No evidence of the occurrence was obtained in the form of afterglow or shooting-stars, nor was any special effort to this end made by astronomers. A suggestion of analyzing great volumes of air for several days after the 20th to detect unusual chemical constituents was not considered worth the trouble, if indeed it were practicable.

The occurrence of this phenomenon took a strong hold on the popular imagination, and in spite of all that was published as to the impossibility of any harm from it or the possibility of even detecting it, ignorant people were genuinely alarmed and great numbers kept watch in the streets of the cities during the night of the 19th, though in fact, as before explained, the earth did not actually pass through the tail until the 20th, if at all.

At the time of the publication of this article no detailed reports of spectroscopic observations have appeared.

WILLIAM BEEBE.

SCIENTIFIC INTELLIGENCE.

I. GEOLOGY.

1. *The Cement Resources of Virginia west of the Blue Ridge*; by RAY S. BASSLER. Bull. No. II-A, Virginia Geological Survey 1909 [1910], pp. x and 309, and 30 plates.—The author has here brought together a great deal of information relating to the limestones and shale formations of the state west of the Blue Ridge. This information has been gleaned from all sources and especially from the extensive travels of the author throughout the state in tracing the various boundaries of the Ordovician formations. Many chemical analyses of the limestones are given. Stratigraphers will find here much new and detailed information regarding the Ordovician, Silurian, and Lower Devonian formations. The guide fossils to the more important cement-bearing formations are illustrated in plates and these will be of great service to the field worker in his age determination of the various deposits. The printing and illustrations are good and the book is above the average of state geological reports. C. S.

2. *Proposed Groups of Pennsylvanian Rocks of Eastern Oklahoma*; by CHAS. N. GOULD, D. W. OHERN and L. L. HUTCHISON. The State University of Oklahoma Research Bulletin, No. 3. Pp. 15 and 1 map. Norman, 1910.—The Pennsylvanian sediments of Oklahoma have a thickness of from 10,000 to 12,000 feet, of which at least three-fourths is shale. At definite intervals in these deposits occur limestones known as the Claremore (Fort Scott), Lenapah, Pawhuska and Wreford. On the basis of the position of these limestones the Pennsylvanian is divided into the Muskogee (9550 feet thick and coal-bearing), Tulsa (about 1200 feet thick), Sapula (about 1000), and the Ralston (about 800) groups. C. S.

3. *Yorkshire Type Ammonites*; edited by S. S. BUCKMAN. London, 1910 (Wesley & Son).—The Jurassic (Lias and Oolite) ammonites of Yorkshire, inadequately described in the early days of geology by Young and Bird, John Phillips and Martin Simpson, are to be illustrated in this work by excellent photographs made mainly by J. W. Tatcher. Each species appears on independent sheets, as in the *Palaeontologia Universalis*, and reproduces the original description and new photographs of the type specimens where these are extant. The editor supplements this information by additional matter that he has gathered during a lifetime, modernizing each species. There are to be about 200 plates.

The work is to appear in about 16 parts of about 12 to 16 plates each and the edition is to be limited to 250 copies. Each part, post free, costs 3 shillings 6 pence. Two parts have now appeared having 24 plates, heliotype and half-tone, and 22 species descriptions. The work is necessary to all students of ammonites. C. S.

II. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *Physical and Commercial Geography: A study of Certain Controlling Conditions of Commerce*; by HERBERT ERNEST GREGORY, ALBERT GALLOWAY KELLER, and AVARD LONGLEY BISHOP. Pp. vi, 469, with 3 plates. Boston, 1910 (Ginn & Co.).—The foregoing work contains the substance of courses given at Yale. In form and style it is a companion volume to Keller's *Colonization*, and is issued under Professor Keller's editorial supervision. Like that work, its purpose is to interpret rather than to enumerate or describe, and to deal with types rather than with details.

The subject matter is three-fold and the work is divided into three corresponding parts. Part I (Gregory) discusses the physical environment, giving attention chiefly to those features which clearly affect the life of man, including, however, a brief account of the struggle for existence among plants and animals. Part II (Keller) is entitled "Relation of Man to Natural Conditions," but actually covers both natural and human controls of commerce, closing with a brief consideration of commercial policies. Part III (Bishop), on "The Geography of Trade," is devoted to the United States and its possessions, the British Empire, and the German Empire. Within each country, however, the material is assembled by industries rather than by sections: for example, there are separate chapters on the vegetable, animal, mineral, manufacturing, transportation, and merchandizing industries of the United States. At the end there is also a chapter on miscellaneous products not produced chiefly in the countries already treated.

In point of method the book is consequently of the fusion type represented by Adams, dealing both with regions and with world industries. It is liberally supplied with cross references and has a good statistical appendix. It is, further, assumed that the student will have access to some text on physical geography and to an atlas of physical, historical and political geography.

The work unquestionably marks a distinct advance in the treatment of economic geography. It is intended primarily for college classes and it will assuredly be welcomed by all who believe that economic geography is (or should be) something more than a compend of isolated and unrelated statistics. The book also contains much of interest to the general reader, provided he be capable of consecutive thought.

EDWARD VAN DYKE ROBINSON.

University of Minnesota.

2. *Soil Fertility and Permanent Agriculture*; by CYRIL G. HOPKINS. Pp. xxiii, 653. Boston (Ginn & Company).—This work is "dedicated to the Association of American Agricultural Colleges and Experiment Stations, the rightful guardians of

American Soils." The author states that his object is "to teach the science of soil fertility and permanent agriculture" by giving facts rather than theories.

The work is divided into four parts and an appendix. Part I (pp. 1-158) embraces a discussion of molecules, valence, certain fundamental chemical laws, the more common chemical elements, radicals, acids, bases, salts, and certain principles of chemical nomenclature. It treats of the chemistry of plant nutrition and synthesis; minerals of agricultural importance; and soil formation, classification, and description, as conducted by the Bureau of Soils of the United States Department of Agriculture. It also contains a brief reference to crop requirements, and to sources of plant food. This part, though possibly capable of being read with profit by the farmer, is too technical in character for those not studiously inclined; it will, however, be found useful to those students of agriculture who have not already laid a broad chemical foundation, and who wish in a brief way to secure at least an elementary idea of the relation of chemistry to soils and to plant production.

Part II (pp. 159-342) is devoted to ground limestone and its use, to the phosphorus compounds more commonly used for agricultural purposes; to organic matter in its relation to soil improvement; and to the fixation of nitrogen by direct bacterial agencies, as well as through the medium of symbiosis. Following a brief chapter on systems of rotations for grain farming, is an extended chapter on farm manures, bone meal, basic slag phosphate, and phosphate rock. The special emphasis on the latter is doubtless due to the efforts of the author to promote its use as a fertilizer on certain of the soils of Illinois.

Part II closes with a lengthy chapter on theories of soil fertility, beginning with those of van Helmont, advanced about three hundred years ago, and extending to certain recent and much disputed theories advanced and supported chiefly or wholly by the Bureau of Soils of the United States Department of Agriculture. The author points out that a recent investigator of the question in Kentucky finds that these views are not generally accepted and taught in the agricultural colleges of the United States, as had been claimed by the Bureau of Soils at a previous congressional hearing. He also takes occasion to express his opinion concerning these views with characteristic energy and vigor.

Part III is devoted to soil investigations by culture experiments. In this connection extended reference is made to the long continued field experiments at Rothamsted, England. Special attention is also given to the field experiments at the Pennsylvania State College, at Wooster, Ohio, in the South, in Canada, and in the author's own state of Illinois. The closing chapter deals with pot-culture and water-culture experiments in comparison with field results. In this connection the author calls attention to certain shortcomings of the paraffined wire-basket method

of the Bureau of Soils, as a means of determining actual soil deficiencies.

Part IV treats of prepared commercial fertilizers, and briefly of indirect manures, of agencies protective against plant diseases and insect pests, of critical periods in plant life, losses of plant food from plants and soils; also of factors of importance in crop production, and of those involving success in farming.

The Appendix contains more or less miscellaneous matter, and tables of agricultural interest.

The work is original in its composition, but is perhaps too controversial to meet accepted ideas, if intended as a text-book. It lays unusual emphasis on certain matters like limestone and phosphate rock, but contains a vast amount of matter which will cause it to be welcomed as a valuable addition to our agricultural literature.

H. J. WHEELER.

3. *Publications of the Smithsonian Institution*.—Bureau of American Ethnology, Bulletin 48. The Choctaw of Bayou Lacomb, St. Tammany Parish, Louisiana; by DAVID I. BUSHNELL, Jr. Pp. viii, 37, with 22 plates and 1 figure. Washington, 1909.

The following volumes in the series of Smithsonian Miscellaneous Collections have also appeared: Vol. 51, No. 4. Hodgkins Fund (Publication 1869). The Mechanics of the Earth's Atmosphere: A Collection of Translations; by CLEVELAND ABBE. Third Collection. Pp. iv, 617.

Vol. 54, No. 3. The Constants of Nature. Part V. A Recalculation of the Atomic Weights. Third edition, revised and enlarged; by FRANK WIGGLESWORTH CLARKE. (Publication 1923.) Pp. iv, 548. Noticed on p. 80 of this volume.

Volume 55. (Publication 1920.) Bibliography of Aeronautics; by PAUL BROCKETT. Pp. xiv, 940.

Vol. 56, No. 1. The Scales of the African Characinid Fishes; by T. D. A. COCKERELL. Pp. 10, with 2 plates. (Publication 1929.) No. 3. The Scales of the Mormyrid Fishes with Remarks on Albula and Elops; by T. D. A. COCKERELL. (Publication 1931.) Pp. 4, with 3 figures. Washington, 1910.

OBITUARY.

JOHANN GOTTFRIED GALLE, the German astronomer and the first observer of the planet Neptune, died at Potsdam on July 10, at the age of ninety-eight years.

Dr. CHARLES ABIATHAR WHITE, the geologist, died at his home in Washington on June 29, at the age of eighty-four years. He was professor of Natural History in the University of Iowa from 1867-73, and in Bowdoin College from 1873-75. He was also State Geologist of Iowa from 1866-70, and was connected as geologist and paleontologist with the U. S. Government Surveys from 1874-92; he was also actively associated with the Smithsonian Institution and the U. S. National Museum. His original contributions to geology and paleontology were numerous and important.

THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

ART. XV.—*The Use of the Grating in Interferometry*;^{*}
by C. BARUS.

1. *Introductory.* It was pointed out elsewhere[†] that on replacing the symmetrically oblique transparent mirror in Michelson's adjustment by a glass grating,[‡] *gg*, fig. 1 (for instance), it is possible, with ordinary plate glass and a non-silvered grating, to produce interferences between pairs of diffracted spectra, $D'D''$, if returned by nearly equidistant mirrors M and N to a telescope in the line D . Both of these spectra are very brilliant and not very unequally so, and the coincidence of spectrum lines, both horizontally and vertically, brings out the phenomenon. This is of the ring type and not of the line type heretofore (l. c.) discussed; but it occupies the whole field of the spectrum from red to violet. One obtains brilliant large confocal ellipses with horizontal and vertical symmetry, and the spectrum lines, simultaneously in focus, may serve either as major or minor axes. Their interferometer motion is twofold in character, consisting of radial motion combined with a drift of the figure as a whole in a horizontal direction. Naturally a fine slit is of advantage, but the experiment succeeds with a wide slit, especially in the red, even after spectrum lines vanish.

Such ellipses (as I shall call them, though they are probably ovals) as have their centers in the field are clearly due to reflection from the same surface as shown in figure 1; curved

^{*} Abridged from a Report to the Carnegie Institution of Washington.

[†] *Science*, xxxii, p. 92, 1910; cf. *Phil. Mag.*, July, 1910.

[‡] My thanks are due to Prof. J. S. Ames, who was good enough to lend me this grating.

lines or ellipses with remote centers are due to simultaneous reflections of the component rays from the opposite faces of the grating, so that the angle of the wedge of glass cannot be excluded. All owe their vertical and horizontal symmetry to the vertical slit and horizontal spectrum. The ellipses are identically present in the successive orders of spectra at once.

These elliptical fringes thus embody with the preceding (l. c.) the common property of being duplex in character; only here the motion of dark rings to or from the centers of the ellipse, as a fine adjustment, is associated with a displacement of the fringes bodily through the spectrum (coarse adjustment).

This displacement may be from red to violet or from violet to red as the virtual air-space increases in thickness, depending upon the adjustment, as will presently appear. In other words, for a given small interferometer motion of mirror, there is in general less displacement of fringes bodily than radial motion of fringes to or from the center. Slight deflection of the mirror is chiefly accompanied by radial motion of the fringes.* The effect thus produced is to give sharpness to the interference pattern, which soon vanishes for approximate adjustments of spectra.

Similarly the micrometer screw produces a rapid passage of the pattern through its maximum size, a play of the screw of $\cdot 1^{\text{cm}}$ being sufficient to pass from fringes of one extreme of small size, through the maximum size to the final extreme. On the other hand, there are many regions of interference; in fact, different groups of interferences may sometimes be in the field at once, or more usually corresponding to slightly different angles between the mirrors and grating.

All admissible angles, provided that symmetry is maintained (the virtual plane of the grating bisecting the angle of the mirrors), bring out the phenomenon. This points to the fact that the earlier phenomenon referred to (l. c.) in which the center or normal ray was virtually at an infinite distance, is now produced near an accessible center, even if this is not actually in the field. However, in the earlier case when the angle of incidence is zero, curved lines may also be obtainable.

Experiments with a silvered grating showed no advantage, whether the transparent film covered the grating or the plane face of the glass. In fact in case of good adjustment the phenomenon is so strong as to need no accessory treatment. This is, in fact, one of its advantages. A great difficulty in adjustment is the occurrence of stationary fringes due to the rear face of the grating. These may even wipe out the spectrum lines; but usually they lie at a finite focus and are not seen

* This changes the effective thickness of the grating.

with a sharp spectrum. Fortunately many positions are available for obtaining the ellipses, so that a satisfactory one is easily found. Unless all overlapping spectra show sharp lines the adjustment is very tedious. The amount of grating space is less than 1 sq. cm., though, of course, a larger size is convenient for experiment.

2. *Special properties.*—The motion of the ellipses bodily across the spectrum, corresponding to the increased or decreased virtual air space (micrometer screw), shows that whereas the vertical dimension or axes (direction of fixed color) do not appreciably change,* the horizontal axes grow rapidly smaller; i. e., the ellipse is more eccentric from red to violet. With the grating used, however (about 2800 lines per cm.), the major axis remained vertical, i. e. the circular form was not reached throughout the first order even in extreme red.

It follows from this that in the second order the major axis of the ellipses will probably be horizontal, and this was found to be strikingly true. The figure, moreover, is necessarily coarser and the lights and shadows in greater contrast. In the third order the ellipses are drawn out horizontally to a correspondingly greater degree. Thus it is clear that with a more dispersive grating, the circular or even the horizontally elongated form must occur in the first order. Spectrum lines are very distinct, particularly in the second order. In all orders of spectra the centers of the ellipses are simultaneously on the same spectrum line and their vertical dimensions are about the same. Hence the spectrum lines may be used instead of cross hairs as they are fixed landmarks among the moving ellipses.

With replica gratings the center of the ellipses is usually remote; i. e., reflection does not easily take place at the grating surface. Apart from this the curved lines are good and strong. Samples must be tried out, in which the lines are as clear as possible in all the overlapping spectra. Six gratings of this kind were examined with about the same results. The centers of the ellipses could only rarely be brought into the field.

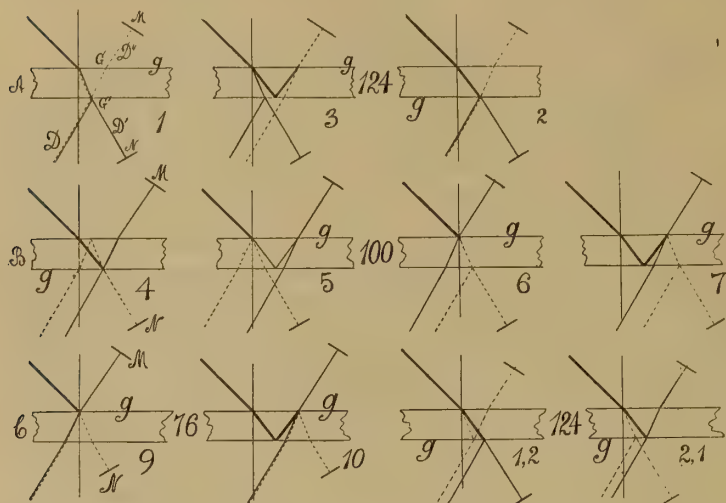
It has been stated that considerable width of slit is admissible. Moreover the focal plane of the collimator (convergent or divergent) light or the focus of the telescope makes little difference, though the condition of parallel rays is naturally preferable. An eye focused for infinity sees the fringes very well without the telescope and they may be also caught on a screen; but coming through a slit they are liable to be dark and the advantage of the telescope is obvious. The second order is particularly accessible for naked-eye observation, and the light and black appearance is accentuated, but they are

* Probably referable to increased refraction and decreased diffraction from red to violet.

liable to be irregular. Inclining the collimator moves the spectrum across the fringes vertically, while inclination of the telescope moves both equally. In this way the centers may often be found. With strong tipping, however, the figure becomes distorted or open above and below, as would be expected. If the light is intensified for projection or naked-eye work, there is also distortion.

It is not necessary and apparently of little advantage to have the reflections from the mirrors *M* and *N* occur at normal incidence. In fact the patch of white light on the grating surface and the return patch of spectrum may be over an inch

FIG. 1.

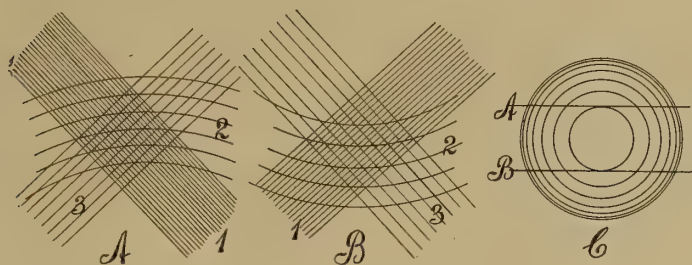


apart. Inasmuch as the spectra are rigorously coincident, it follows that (apart from the refraction of the thick plate glass) the grating must be symmetrical with respect to the mirrors; i. e., intersect the angle between them. Very little difference of size or shape is observable between extremes of such adjustment. Thus I rotated the grating about 10° (larger angles being unavailable), without appreciable effect, after one of the mirrors had been correspondingly adjusted.

On examination of the effective air distances of the mirrors *M* and *N* from the grating, it is found that three positions are favorable to interference; in the first case (case A), *M* is farther away than *N* from the corresponding faces of the glass plate; in the second (case B), they are about equidistant; finally in the third (case C), *N* is farther away, symmetrically with the first adjustment. For each case the admissible play

of mirror (micrometer screw) does not much exceed 1^{mm} for ordinary magnification. The second equidistant adjustment brings out the lines or ellipses with distant centers, and there are usually three types easily found (after one has appeared), by slightly inclining either mirror around a horizontal axis by a tangent screw. Thus as seen in fig. 2, fine lines, say 135° to the horizontal, coarse, nearly circular lines, concave downward or upward as the case may be, and finally broad lines, say 45° to the axis, may appear in succession. If the grating is rotated 180° around its normal, convexity upward changes to concavity upward, showing the wedge angle of the glass plate to be effective. The micrometer screw will pass any of these forms through a succession of inclinations

FIG. 2.



corresponding to the eccentric intersection of a group of concentric circles by a straight line. This is also shown in fig. 2; at *A* and *B* as observed for a fixed air space and at *C* on moving the micrometer in the *A* and *B* cases. These figures cover the coincident spectrum fields only. A solitary part of the field shows no interferences. For adjustment it is, therefore, necessary to cut off the spectra sharply above and below by limiting the length of slit. Of the three or four spectra present the coincidence may then be secured with least difficulty. With each such coincidence there goes a definite position of the micrometer screw (interferometer), and this is the initial difficulty of adjustment; i. e., to coördinate the various spectrum coincidences with the three screw readings.

The non-equidistant case of mirrors and grating corresponds to the ring types with the centers in the field. Hence both reflections take place from the same face of the grating. When the distance GM is shorter, $G'N$ longer, I have noticed two or even three ellipses successively in the field, obtained by slowly inclining the mirror N about the vertical (tangent screw), with their centers in turn in the yellow-green, the blue and the green of the spectrum. They do not occur together. On turning

the micrometer screw clockwise, they move from red to violet and vice versa.

When the distance GM is longer and $G'N$ shorter, rings also occur; but only a single set was found. The spectrum lines not being clear, finding them was a matter of discrimination. When the micrometer screw is turned clockwise, however, they marched from violet to red, i. e., in *opposite* direction to the preceding. Thus the virtual air space $M-N$, which was increased in the preceding case, is here being decreased. This space is not generally zero. Moreover, violet travels radially more rapidly than red, for the same micrometer displacement. Hence the drift of ellipses agrees with the horizontal radial motion of the violet.

It is an astonishing result that when the grating is reversed (front face put rearward, but leaving the air space unchanged) the ring type is left in the field; though the solitary ring type may change to the multiple type. This is true for case *A* or case *C*. It is also true for the eccentric type case *B*, where line types single or multiple reappear at slightly different mirror angles. Briefly, rotation has no effect on the march of ellipses through the spectrum; but in case *B* it changes convex lines downward to concave lines, and vice versa. Nor has reversal of grating any effect on the march. The position of the grating with respect to the mirrors (three places being available) alone determines this result, certainly in the opposed cases *A* and *C*, and probably in case *B*.

The use of a compensator in either of the component rays is always accompanied by the two effects in question; i. e., there is both relatively large radial motion of the fringes and relatively small displacement. Within the field of the telescope one may therefore be evaluated in terms of the other, the two having the stated relation of coarse and fine adjustments. In case *B* the fringes will rotate, expand, or contract.

3. *Elementary theory.*—The endeavor must now be made to explain these results more in detail. For this purpose the diagrams of fig. 1 may be consulted.

In the grating used at an incidence of about 45° , the angle of diffraction in the first order was about $32^\circ 39'$ for the D_2 sodium line, there being about 2,847 lines to the cm., corresponding to a grating space of $D = .0003512^{\text{cm}}$. Thus $\lambda/D = .1677$. The index of refraction was assumed to be 1.53 for the same line.

The diagrams are drawn for an angle of incidence of 45° and for normal reflection from the mirrors M and N . In case of the grating given, the three positions of the grating at which interferences occur were about $.6^{\text{cm}}$ apart and are marked 124, 100, and 76 scale parts, on the micrometer screw normal to the

grating. In other words, it was convenient to move the grating at the center of the spectrometer, rather than the mirrors M and N adjustably attached near the edge of the plate graduated in degrees.

In group A at 124, the short air path is to M , the long path to N ; in group C at 76, the reverse is true. In group B at 100, the system is self-compensating and the air paths about equal.

In all cases the angle of diffraction, θ , is less than the angle of incidence, i . There are, of course, corresponding cases, $\theta > i$, which have not been drawn, because they merely duplicate the cases given, at a different angle. It is assumed that after more than one direct reflection or one diffraction, the interferences are no longer observable.

The diagrams 124 and 76 show that the two reflections of the component rays at the grating take place at the same surface. Hence the occurrence of centered figures or rings. On the contrary, the reflections in diagram 100 take place at the two different faces of the grating, respectively. Hence the angle of the grating is included and liable to produce eccentric ring systems. The center may be so far off that the dark lines are nearly straight, but they change their inclination as the vertical projection of the center moves horizontally through the field.

Some of these cases may coalesce in practice or they may destroy each other, more or less. I have taken a single incident ray from which may come two parallel emergent rays, which are brought to interfere by the telescope. It would have been just as convenient to have taken the two corresponding incident rays which interfere in a single emergent ray. From the position of the mirrors it is clear that the regularly refracted rays are not returned. Only rays *first diffracted* at the grating (where they may also be reflected) are returned by the mirrors.

As a whole we may distinguish two typical cases,—those in which both component rays are diffracted as in number 1 or refracted as in number 2, and those in which one component ray is refracted and the other diffracted. If i and θ' are the angles of incidence and diffraction in air, and r and θ the corresponding angles of refraction and diffraction in glass, the path differences Δx are as follows:

- No. 1. $\Delta x = 2\mu e / \cos \theta = 2 \cdot 2^{\text{cm}}$.
 “ 2. $= 2\mu e / \cos r + 2e \sin \theta' (\tan r - \tan \theta) = 2 \cdot 5^{\text{cm}}$.
 “ 3. $= 2\mu e / \cos \theta = 2 \cdot 2^{\text{cm}}$.
 “ 4. $= \text{Zero}$.
 “ 5. $= -2\mu e / \cos \theta + 2\mu e / \cos r + 2e \tan r \sin \theta'$.

No. 6.	Zero.
" 7.	"
" 8.	"
" 9.	$\Delta x = -2\mu e / \cos \theta = 2 \cdot 2^{\text{cm.}}$
" 10.	$= -2\mu e / \cos \theta = 2 \cdot 2^{\text{cm.}}$

Here μ is the index of refraction and e the thickness of the glass plate of the grating, and excess of path for the M ray is reckoned positive. These paths must be compensated by corresponding decrements and increments respectively of the air paths GM and GN . Ordinarily, these path differences in glass being fixed for the given angles θ , would fall away; but they vary essentially with color, and hence the degree of compensation is never the same for all colors.

Furthermore, although the wave fronts of the two rays are the same on emergence, this does not imply coincidence of phase even in such cases as numbers 1 and 2, for instance: the absolute lengths of paths in glass are quite different, although their differences are the same. Consequently the cases 1 and 2 would again interfere if superimposed, one case being first diffracted and the other first refracted.* The path differences are respectively,

$$\text{No. 1, 2: } \Delta x = e \left(\frac{3\mu}{\cos \theta} - \frac{\mu}{\cos r} - (\tan r - \tan \theta) \sin \theta' \right) = 2 \cdot 1^{\text{cm}}$$

$$\text{No. 2, 1: } = e \left(\frac{\mu}{\cos r} + \frac{\mu}{\cos \theta} + (\tan r - \tan \theta) \sin \theta' \right) = 2 \cdot 3^{\text{cm}}$$

If the grating is moved Δz cm. parallel to itself to be equal to these increments Δx , at an angle $90^\circ - \theta'$ to the grating,

$$2 \Delta z = \Delta x \cos \theta$$

remembering that Δx and Δz are passed over twice.

Thus it is not surprising that so many cases were identified. It is also apparent that the air compensations are very different and hence identification is facilitated. Finally, since a vertical slit and collimator are used, the section of a beam of light passing through the grating by a horizontal plane consists of parallel rays; the section by a vertical plane, however, is convergent.

It is interesting to find the numerical data for the above equations, assuming that $i = 45^\circ$, $\theta' = 32^\circ 39'$, $e = .68^{\text{cm}}$, $\mu = 1.53$ (estimated), $\lambda/D = .1677$, for the sodium line of the spectrum. The results are given with the equations. Their mean value is about $2 \cdot 3^{\text{cm}}$, which is equivalent to a displacement of grating $\Delta z = .6^{\text{cm}}$, the value actually found.

It follows, moreover, that the center of the ring system order, $n = 0$, must move from red to violet or the reverse,

* A glass plate with identical gratings on both sides is here in question.

inasmuch as the compensation takes successively, at each color, in the same way. Although the equations hold only for the center and the symmetrically oblique rays belonging to the rings have not been given consideration, an approximate computation of the motion of the ring centers may nevertheless be attempted. The relations numbers 1, 3, 9, and 10, which are more important, may be taken. Here is n in the order of the fringe, D the grating space, $2x$ the difference of air path,

$$2e\mu / \cos \theta + 2x = n\lambda ;$$

this with

$$\sin i - \sin \theta' = \lambda / D, \sin \theta' = \mu \sin \theta, d\mu / d\lambda = - \cdot 015 \mu / \lambda,$$

an experimental interpolation equation for the given glass, will on differentiation yield dz/dn , dz/de , $dz/d\lambda$, etc. From these qualitative interpretation of the above and the following data is obtainable; but quantitatively they are too crude, because they ignore the essential feature of oblique reflection from M and N . For the radial motion, if dz/dn is the displacement of grating normal to itself per fringe,

$$\frac{dz}{dn} = \frac{\lambda \cos \theta}{4}$$

is near the truth.

Omitting these equations, an example of the displacement and radial motion in a given experiment may be adduced; the former were fully 16 times less sensitive per fringe than the latter. The displacement is thus a coarse adjustment in comparison with the usual radial motion of the fringes and this is the distinct advantage of the present method for many purposes. It is like a scale division into smaller and larger parts, where the enumeration of small parts alone would be confusing or impossible. The ratio of the micrometer value of displacement and radial motion per fringe may be given any value since $dz/d\lambda \propto \mu e$. Thus $e = \cdot 42^{\text{cm}}$ would correspond (for the same μ) to 10 radial fringes for one displacement fringe. Again if $e = \cdot 04^{\text{cm}}$ the two micrometers would be equally sensitive. Or for $e = \cdot 01^{\text{cm}}$ (microscope cover glass), the lateral displacement is actually four times more sensitive than the radial motion.

The sodium lines here make admirable cross hairs and the ocular itself need have none. The conditions are the same in the second order, and the coarser rings and spectrum lines are often easier to count.

4. *Compensator*—It is not necessary, however, to use thin glass, for if a compensator is provided, i. e., if the grating is on the common plane between two thicknesses of identical

plane-parallel glass plates, one of which carries the grating, the ideal plane in question is provided. The ellipses in this case would be infinite in size and their displacements infinitely large. By partial compensation (compensator thinner) ellipses of any convenient size and rate of displacement may therefore be provided at pleasure. The following table gives some rough experimental data where z is the advance of the micrometer screw normal to the grating, i. e., the displacement of the grating to move the center of fringes from the D to the b lines of the spectrum, e' the thickness of the compensator plate parallel to the mirror M or N as stated.

Displacement of ellipses from the D to the b line, by moving the grating Δz cm. normal to itself. $i=45^\circ$, nearly. Grating: $e=.68$ cm.: $D = .000,351$ cm.; $\mu = 1.53$ (estimated). Compensation shown by negative sign. Position p taken while the sodium line was the major axis.

Compensator thickness $e' \times 10^2$	Position of grating p	Micrometer displacement $\Delta z \times 10^4$	No of fringes D to b	Displacement per fringe $10^4 \times dz/dn$	Ellipses	Side of compensator
cm.	cm.	cm.		cm.		
-48	.05	30	12	2.5	Very large	N
-44	.08	35	----	----	do.	N
-29	.12	45	----	----	Large	N
-10	.20	65	----	----	Mean	N
+48	.38	115	44	2.6	Very small	M
-65	.00	10	4.5	2.3	Enormous	N
± 0	----	70	28	2.5	Mean	None

Rotation of the compensator offers the usual easy method of adjustment. In the second order the first rings, on compensation, usually more than fill the field. This is of course eventually the case in the first order also. With very perfect compensation the ellipses are quite eccentric and the opposed lines nearly vertical and straight. Hence their motion, partaking of the twofold character specified, is complicated but usually opposite in direction on the two sides of the center for the same micrometer displacement. The whole phenomenon may vanish within a half mm. of play of the grating, passing from fine lines through enormous ellipses back into reversed fine lines, all nearly vertical.

The displacement of the grating by the micrometer screw is the same per fringe, no matter whether the ellipses are large

or small, and in the last table it was about $\cdot 00025^{\text{cm}}$ per fringe. The displacement at the mirror would be more than twice this. The radial motion per fringe is of the order of wave-length. Naturally the position p of the grating changes parallel to itself linearly with the thickness e' of the compensator, supposing other conditions the same, so that p , z , and dz/dn all vary linearly with e' , the thickness of the compensator. Finally, the virtual thickness of the air film can only be brought to vanish by compensation, otherwise spectra if equidistant are unequal in length from red to violet, and vice versa.

The full equations for the amounts of displacement, etc., requires an evaluation of $d\theta/dn$, which in turn must take into consideration that reflection from the mirrors cannot in general be normal, except for the one color instanced above. This investigation will have to be reserved for another communication.

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ART. XVI.—*Fox Hills Sandstone and Lance Formation*
("Ceratops Beds") in South Dakota, North Dakota and
Eastern Wyoming;* by TIMOTHY W. STANTON.

THE Laramie question is a perennial problem for stratigraphers and paleontologists, but with the continued rapid accumulation of facts, as the detailed investigation of the stratigraphy is carried over the entire area involved, it is reasonable to hope that the problem will not be perpetual.

At the present time one of the most important points at issue is the relationship of the Lance formation† ("Ceratops beds") to the Laramie formation and to the conformable Cretaceous sequence beneath the Laramie. Some geologists hold that the Lance formation wherever it has been studied rests unconformably on the Laramie or some older formation and that the unconformity beneath it represents a long, complex epoch of elevation and erosion. In this paper evidence will be presented to show that in the rather widely distributed areas discussed there is a real transition from the marine Cretaceous Fox Hills sandstone into the Lance formation and that sedimentation was practically continuous from the one into the other and probably on through the Fort Union.

The data to be discussed were obtained in three areas mostly during the summer of 1909. One of these, which includes the Cheyenne River and Standing Rock Indian Reservations in northern South Dakota and southern North Dakota just west of the Missouri River, was examined for coal lands by Messrs. A. L. Beekly, Max Pishel and V. H. Barnett under the general supervision of Mr. W. R. Calvert. This investigation afforded an excellent opportunity for the study of the Fox Hills sandstone in its typical area and of its relations with the overlying Lance formation. A second area, which has been described in some detail by Prof. A. G. Leonard, is along the Little Missouri from Marmarth to Yule in the southwest corner of North Dakota, where I spent five days. The third area is the well known Lance Creek region in Converse County, eastern Wyoming, where Hatcher made his great collection of the Triceratops fauna. Nearly a week was spent here in company with Messrs. M. R. Campbell and R. W.

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† The name Lance formation has recently been adopted by the United States Geological Survey for the "Ceratops beds" of eastern Wyoming and adjacent areas. It is an abbreviated form of the term "Lance Creek beds" which J. B. Hatcher applied to these deposits in 1903 (*American Geologist*, vol. xxxi, p. 369) with the statement that the name is taken "from the principal stream in the region where they are best represented in Converse County, Wyoming."

Stone. The three areas, though separated by intervals of 100 to 150 miles, all belong to the same general region, throughout which it is evident that closely similar conditions prevailed in the closing stages of the Cretaceous.

Standing Rock and Cheyenne River Indian Reservations.

A detailed description of this area will be given by Mr. Calvert and his assistants in a report which is in preparation. For the present purpose it is only necessary to direct attention to a few points. The area lies on the west side of the Missouri River between Cheyenne River on the south and Cannonball River on the north and it is divided into three approximately equal parts by Moreau and Grand Rivers, tributaries to the Missouri from the west.

The rocks are little disturbed and usually appear horizontal in ordinary exposures, but a more general study of their distribution shows that they dip a few feet in the mile toward the north or northwest. The lowest formation exposed is the Pierre shale, the upper part of which is seen in the valleys of all the streams mentioned except the Cannonball. Above the Pierre is the Fox Hills sandstone in many places forming bluffs for long distances along the streams. This is the highest marine Cretaceous formation in the section. It extends up the Missouri as far as old Fort Rice, North Dakota, a few miles above the Cannonball, and underlies the higher ground in a broad belt of country southwest of that point. Overlying the Fox Hills sandstone is the less resistant non-marine Lance formation which in published reports has been called "Ceratops beds," "Laramie," "lower Fort Union" and "somber beds." It frequently forms badlands in the inter-stream areas on the reservations and extends up the Missouri valley to Bismarck and beyond. As the streams have cut through both the Lance formation and the Fox Hills sandstone for long distances, the relations between the two formations are easily studied.

The Fox Hills sandstone was first named by Meek and Hayden* in 1861, who stated that it "is most distinctly marked at Fox Hills, between Cheyenne and Moreau Rivers, above Fort Pierre." In the words of their description "this formation is generally more arenaceous than the Fort Pierre group, and also differs in presenting a more yellowish or ferruginous tinge. Towards the base it consists of sandy clays, but as we ascend to the higher beds, we find the arenaceous matter increasing, so that at some places the whole passes into a sandstone. It is not separated by any strongly defined line of demarcation from the formation below, the change from the

* Proc. Acad. Nat. Sci. Phila., vol. xiii, pp. 419, 427.

fine clays of the latter to the more sandy material above being usually very gradual. Nor are these two formations distinguished by any abrupt change in the organic remains, since several of the fossils occurring in the upper beds of the Fort Pierre group pass up into the Fox Hills beds, while at some localities we find a complete mingling in the same bed of the forms usually found at these two horizons." The total thickness of the formation was then estimated at 500 feet, but in previous papers dealing with only the typical area the thickness was given as 100 to 150 feet, an estimate which is nearer the truth for this particular area.

The variable character of the formation is indicated by Meek and Hayden's description just quoted and this variability as to details becomes impressive after a number of local sections have been examined. In some exposures nearly the whole formation is a soft, friable, cross-bedded gray or yellowish sandstone, usually with many iron-stained concretions and indurated masses as on Cannonball River, 6 miles above its mouth, where single exposures show 60 feet of sandstone and the base of the formation is not seen. At other places similar sandstones occur at the top and at the bottom and include indurated beds of considerable extent, while the middle portion of the formation is made up of more or less sandy shale in bands a few inches thick of alternating lighter and darker color. This banded shale contains considerable vegetable matter in the form of stems and comminuted fragments and in general lithologic character it closely resembles some parts of the overlying Lance formation. At still other localities within short distances either the upper sandstone or the lower one or sometimes both of them are found to thin or disappear as distinct beds, their places being taken by more shaly material. The whole formation gives ample evidence of irregular sedimentation in the presence of strong, variable currents.

The irregular character of the formation may be shown by describing a few local sections beginning on Grand River near the mouth of Dirt Lodge Creek about 20 miles southwest of McIntosh, South Dakota. On the south side of the river the following section is exposed:

<i>Section on Grand River near the mouth of Dirt Lodge Creek.</i>		Feet
1. Hard gray sandstone with <i>Tancredia americana</i> and <i>Halymenites</i>		15
2. Banded shale with <i>Fasciolaria scarboroughi</i> , <i>Thracia</i> , <i>Anchura</i> , <i>Scaphites</i> , etc.		50
3. Hard gray sandstone with <i>Tancredia americana</i> and <i>Halymenites</i>		10
4. Soft yellowish massive sandstone		40
5. Dark clay shale referred to the Pierre, exposed		75

All except the basal member of the section belong to the Fox Hills.

The hard sandstones of Nos. 1 and 3 are merely local indurations which in some places are seen to pass horizontally into soft friable sandstone. Other exposures in the neighborhood especially on the north side of Grand River show that the upper sandstone, No. 1, is very near the top of the Fox Hills. About a mile northwest of the mouth of Dirt Lodge Creek and not more than two or three miles from the section just described the upper sandstone is represented by a few feet of sandy shale which pass upward into similar sandy shale about 4 feet thick, which is filled with brackish-water fossils including *Ostrea glabra* M. & H., *O. subtrigonalis* E. & S., *Anomia micronema* Meek, and *Corbicula subelliptica* var. *moreauensis* M. & H. Immediately above this brackish-water bed without any apparent stratigraphic break are shales, soft sandstones and carbonaceous beds, weathering into badlands, and locally containing abundant remains of Triceratops, Trachodon, turtles and other members of the Lance formation fauna.

About 3 miles east of the mouth of Dirt Lodge Creek in section 12, T. 20 N., R. 22 E., the oyster bed at the top of the Fox Hills is again exposed with the basal portion of the Lance formation above it. Vertebrate fossils of the types just mentioned are here abundant about 30 or 40 feet above the oyster bed.

A few miles farther east on Grand River near the mouth of Fire-steel Creek the contact of the oyster bed with the underlying sandstone shows an irregular surface suggesting an unconformity, but facts to be recorded on subsequent pages will show that the oyster bed actually belongs to the Fox Hills sandstone as proved by its fauna.

Another instructive section in T. 15 N., R. 18 E., on Thunder Butte Creek about 30 miles south of Grand River, is as follows:

Section on Thunder Butte Creek.

	Feet
1. Friable gray and yellow sandstone with many large indurated masses locally containing an oyster bed with an abundant brackish-water fauna mingled with many specimens of marine Fox Hills species (see list on p. 180). Some evidence of channeling and erosion at base of oyster bed.....	20
2. Banded shale and shaly sandstone.....	50
3. Dark, somewhat sandy, shale referred to the Pierre with <i>Avicula linguiformis</i> E. & S., <i>Mastra warrenana</i> M. & H., etc. Exposed.....	30

In this section the sandstone forms relatively a small part of the Fox Hills and the absence of a prominent lower bed makes the base of the formation uncertain. The fossils from the underlying shale so far as it is exposed belong to the Fox Hills fauna. The oyster bed in the upper member of the section at one point is a conspicuous indurated very fossiliferous bed fully fifteen feet thick, but it thins abruptly within a few yards to two feet or less, the variation being due to the irregularity of its base. In other exposures less than $\frac{1}{4}$ mile distant its position is only marked by scattering brackish-water shells. The Lance formation is seen in neighboring higher exposures.

The exposures a few miles farther south in T. 14 N., R. 19 E., on the south side of Moreau River show a section similar to that last described, but they give a better contact with the overlying Lance formation.

Section on south side of Moreau River.

	Feet
1. Soft sandstone, sandy shale, and carbonaceous shale in alternating beds a few feet thick, forming the base of the Lance formation. Fossil plants at the top and associated with <i>Unio</i> in the lower 4 feet (Lot 5423. See list below), -----	40
2. Soft friable cross-bedded gray sandstone irregularly stratified with bands of darker sandy shale. Large concretions or indurated masses near the base contain Fox Hills species of <i>Scaphites</i> associated with <i>Corbicula</i> (No. 5969. See list on p. 180). The <i>Corbicula</i> occurs in abundance to the top of the bed -----	30 to 40
3. Banded shale with a few marine Fox Hills fossils -----	60
4. Dark, somewhat sandy, shale referred to the Pierre but containing a Fox Hills fauna. Exposed -----	50

The fossil plants collected in the lower 4 feet of the Lance formation at this place have been examined by Dr. F. H. Knowlton, who refers them to the Fort Union and identifies the following species:

5423.	<i>Thuya interrupta</i> Newb.
	<i>Sequoia Nordenskiöldi</i> Heer
	<i>Populus cuneata</i> Newb.
	<i>Viburnum marginatum</i> Lesq.
	<i>Sequoia acuminata</i> ?? Lesq.
	<i>Leguminosites</i> ? n. sp.
	<i>Cyperacites</i> sp.
	<i>Monocotyledon</i> —new

This list is given for the purpose of showing that the Fort Union flora ranges to the base of the Lance formation. All the other plant collections from this formation were likewise referred to the Fort Union.

The minimum thickness of sandstone in the Fox Hills of this region was seen in a section at Rattlesnake Butte near the northwest corner of T. 11 N., R. 19 E., about 15 miles south of Moreau River.

Section at Rattlesnake Butte, South Dakota.

	Feet
1. Hard gray sandstone with <i>Glyptostrobus Unger</i> Heer, <i>Taxodium occidentale</i> Newb., <i>Viburnum marginatum</i> Lesq., <i>Cornus Newberryi</i> Hollick, and other plants referred to the "lower Fort Union"	25
2. Clay shale	10
3. Carbonaceous shale	4
4. Clay shale with some carbonaceous bands	8
5. Carbonaceous shale	7
6. Soft, friable yellowish sandstone with large concretions or indurated masses in the upper part, forming top of Fox Hills	12
7. Banded shale with a few marine Fox Hills shells	90

This is the base of the local exposure, but in the neighborhood dark shale referred to Pierre is seen not many feet lower. The upper 5 members evidently belong to the Lance formation. No. 6 did not yield any fossils at this point, but on Mud Butte, about 5 miles south, the same horizon yielded the mixture of brackish-water and marine Fox Hills species listed as No. 5870 on p. 179.

It is evident from these sections that the Fox Hills sandstone is variable throughout its thickness. The lower part is no more constant than the upper. Its base is therefore indefinite, and it is by no means certain that the top of the dark shale necessarily taken as the top of the Pierre in the different sections represents exactly the same geologic horizon. The fauna of at least the upper 100 feet of Pierre shale is essentially a Fox Hills fauna, indicating shallow marine waters and differs very little from that of the overlying sandstone, while it lacks all the species which in other areas are especially characteristic of the Pierre.

The most common and characteristic species of this fauna in the Fox Hills sandstone and the upper part of the Pierre shale are as follows:

- Avicula linguiformis* E. & S.
- Avicula nebrascana* E. & S.
- Cucullæa shumardi* M. & H.
- Limopsis striatopunctata* E. & S.
- Leda* (*Yoldia*) *evansi* M. & H.
- Nucula cancellata* M. & H.
- Nucula planimarginata* M. & H.

Lucina occidentalis (Morton)
Tancredi americana M. & H.
Protocardia subquadrata E. & S.
Callista deweyi M. & H.
Tellina scitula M. & H.
Macra warrenana M. & H.
Cuspidaria ventricosa (M. & H.)
Lunatia occidentalis M. & H.
Lunatia concinna H. & M.
Lunatia subcrassa M. & H.
Anchura (*Drepanochilus*) *americana* (E. & S.)
Pyropsis bairdi M. & H.
Fasciolaria (*Piestochilus*) *culbertsoni* M. & H.
Fasciolaria buccinoides M. & H.
Pyrifusus newberryi M. & H.
Fusus (*Serrifusus*) *dakotensis* M. & H.
Cylichna volvaria M. & H.
Haminea minor M. & H.
Cinulia concinna M. & H.
Sphenodiscus lenticularis (Owen)
Scaphites conradi (Morton)
Scaphites conradi var. *intermedius* Meek
Scaphites abyssinus (Morton)
Scaphites nicolleti (Morton)
Scaphites cheyennensis (Owen)

At some localities as on Grand River near Dirt Lodge Creek the sandstones are filled with *Tancredia americana* M. & H., with very few other species.

At the top of the Fox Hills sandstone with its purely marine fauna there is a rather thin but widely distributed brackish-water bed, already several times referred to, which contains *Ostrea*, *Anomia*, *Corbicula*, *Melania*, etc., in great abundance. The zone in which this fauna occurs varies in thickness from 3 or 4 feet up to 40 feet and is lithologically very similar to the underlying marine beds, but its base is irregular at many places and shows channeling and other evidence of erosion. It was therefore regarded by the field geologists as the basal member of the overlying Lance formation resting unconformably on the Fox Hills. In the study of this brackish-water bed evidence was found at several localities, distributed over a considerable area, that there is a distinct transition without a break of any importance between the marine Fox Hills sandstone and the brackish-water deposit. The paleontologic evidence consists of distinctive Fox Hills species belonging to such marine genera as *Scaphites*, *Lunatia*, and *Tancredia*, found directly associated in the same bed with the brackish-water forms and occurring with them in such a way that they must have lived together or near

each other and been imbedded at the same time. Such a mixture of faunas was found at five localities, as shown in the following lists. The marine Fox Hills species are marked with an *.

5870. Mud Butte, SW 1/4 Sec. 25, T. 11 N., R. 18 E., about 20 miles south of Moreau River.

Ostrea subtrigonalis E. & S.

Ostrea glabra M. & H.

Anomia micronema Meek

Modiola meeki (E. & S.) ?

Corbicula occidentalis M. & H.

Corbicula cytheriformis M. & H.

Corbicula subelliptica var. *moreauensis* M. & H.

Panopæa? sp.

* *Teredo* sp.

Neritina bruneri White

Neritina (*Velatella*) *baptista* White

Melania insculpta Meek var.

Melania wyomingensis Meek

Viviparus sp.

Melampus sp.

* *Scaphites conradi* (Morton)

The stratigraphic relations at this locality have been described in connection with the Rattlesnake Butte section on p. 177.

5871. Sec. 2, T. 11 N., R. 19 E., about 4 miles south of Moreau River.

Ostrea subtrigonalis E. & S.

Anomia micronema Meek

Corbicula subelliptica var. *moreauensis* M. & H.

* *Lunatia concinna* H. & M.

Mr. Barnett reports that the fossils were obtained from a small exposure of friable sandstone in which the fossiliferous band is two feet thick.

5938. SE 1/4 SW 1/4 Sec. 18, T. 17 N., R. 26 E.

Ostrea glabra M. & H.

Anomia sp.

Corbicula occidentalis M. & H.

* *Tancredia*? n. sp.

Melania insculpta Meek

* *Scaphites conradi* (Morton)

Mr. Barnett states that the fossiliferous bed is an indurated sandstone about 40 feet thick at the top of the Fox Hills.

5969. Sec. 27, T. 14 N., R. 19 E. South side of Moreau River, above Thunder Butte P. O.

Corbicula nebrascensis M. & H.

Melania insculpta Meek

* *Scaphites conradi* var. *intermedius* Meek

* *Scaphites cheyennensis* (Owen)

The section in which this collection was obtained is described on p. 176.

5975. North side of Thunder Butte Creek near south line Sec. 12, T. 15 N., R. 18 E.

Ostrea glabra M. & H.

Anomia micronema Meek

Corbicula occidentalis M. & H.

Corbicula cytheriformis M. & H.

Corbicula subelliptica var. *moreauensis* M. & H.

* *Tancredia americana* M. & H.

* *Tancredia* ? n. sp.

* *Lunatia subcrassa* M. & H. ?

Melampus sp.

Melania wyomingensis Meek

Melania insculpta Meek

* *Scaphites conradi* (Morton)

The section at this locality is described on p. 175.

The brackish-water species elsewhere are found in the Laramie and in the non-marine formations of the Montana group, but the marine forms, especially the ammonoids, which give the best evidence as to age, belong to the Fox Hills fauna. It is clear from these occurrences that there was no erosion interval of any geological importance between the marine Fox Hills and the overlying brackish-water bed, and that the latter belongs to the Fox Hills epoch of sedimentation.

Above the brackish-water horizon is the fresh-water Lance formation consisting of soft sandstones, shales, thin coals and carbonaceous shales, retaining the same general character through 500 or 600 feet of strata. The flora from these beds, ranging from the bottom to the top, is referred by Dr. Knowlton to the Fort Union. Vertebrate fossils are common, especially in the lower 100 feet and ranging down to the base. These include the dinosaurs *Triceratops* and *Trachodon* with several other genera that are characteristic of the Lance formation fauna elsewhere.

The history of the epoch immediately following the Fox Hills sedimentation in this region has received two very different interpretations. One is the view here presented, that without any unrepresented interval of importance there was gradual transition from marine conditions through brackish-waters to the land and fresh-water conditions that generally prevailed during the deposition of the Lance formation. The other

adopts the current interpretation of the evidence from fossil plants which refers the Lance formation to the Fort Union formation, assigned to the Eocene, and requires a period between the close of the Fox Hills and the beginning of the Lance formation long enough to represent the Laramie, Arapahoe, and Denver formations of the Denver Basin, together with the long intervals of erosion which preceded the Arapahoe and the Denver, and another interval supposed to be between the Denver and the Fort Union. It has been asserted that the erosion preceding Arapahoe deposition cut down through 14,000 feet of stratified rocks in the Denver area. It is worthy of note that there are no Fort Union rocks or floras known in the Denver Basin and no plant-bearing formations older than the Lance formation in the area now under discussion.

Early in their field work last summer the geologists had determined that the Lance formation immediately overlies the Fox Hills, and had received reports that the plants from near their base belong to the Fort Union flora. Special search was therefore made for physical evidence of the unconformity and hiatus which the facts seemed to demand. The only horizon at which a somewhat generally distributed break was suggested is at the irregular base of the brackish-water bed, and this irregular surface was therefore tentatively taken as the base of the Lance formation on the supposition that it indicated a hiatus in the sedimentary record equivalent to the Laramie and post-Laramie formations of the Denver Basin. That there was no such break in the record at this horizon is definitely proved by the occurrence of ammonoids and other fossils characteristic of the marine Fox Hills in the brackish-water bed as already described. The brackish-water fossils in themselves give evidence of their Cretaceous age. In the first place, almost all of them belong to species that in other areas occur in unquestioned Cretaceous formations. Secondly, brackish waters with such a fauna as the one in question must have had connection with the sea and no connection with Tertiary seas is probable. Marine waters retreated from the region of the Rocky Mountains and Great Plains at or just before the close of the Cretaceous, and there is no evidence that the sea has approached the region since that time. The nearest marine deposits of Eocene or later age are in the lower Mississippi valley and in the Gulf coastal plain of Texas. This fact gives special importance to the occurrence of an oyster bed 500 feet above the base of the Lance formation on the Little Missouri River, North Dakota, which will be described on a subsequent page.

It may be suggested that there is a stratigraphic break between the brackish-water and fresh-water horizons, but no

evidence of such a break has been found there. It is true that at various levels throughout the Lance formation there is evidence of current action and irregular deposition shown in cross-bedding, varying thickness and uneven surfaces of sandstones, and similar phenomena. Such features are characteristic of continental deposits, and have little weight as evidence of important unconformities unless supported by other lines of evidence. In this case all the irregularities observed seem to be of purely local character.

Valley of the Little Missouri from Marmarth to Yule, North Dakota.

In the southwest corner of North Dakota, near the town of Marmarth on the Chicago, Milwaukee & Puget Sound Railway, the valley of the Little Missouri cuts down through the Lance formation and the Fox Hills into the Pierre, and shows a section comparable with those in the Indian reservations which we have been discussing. The area has been described by Prof. A. G. Leonard,* and my observations added little to the facts he has recorded.

The Pierre shale is exposed on Little Beaver Creek, about 5 miles southwest of Marmarth, and yields a typical Pierre fauna with less admixture of Fox Hills species than is found in the top of the Pierre in the reservations.

Immediately above the Pierre shale is banded shale with a thickness of about 40 feet overlain by 40 feet of soft massive sandstone, yellow with iron-stained bands and concretions below, grading up into gray sandstone above. This sandstone yielded a few marine fossils, including *Leda* (*Yoldia*) *evansi*, *Tellina scitula*, *Entalis*? *paupercula* and *Halymenites major*, which confirm Leonard's reference of the sandstone to the Fox Hills. In several bluff exposures along the creek the top of the gray sandstone shows an uneven eroded surface which Professor Leonard has photographed and described† as an unconformity in the following words: "It is well shown at two points on Little Beaver Creek in section 7, T. 132 N., R. 106 W. Here the massive sandstone forming the top of the Fox Hills is seen to have undergone erosion before the deposition of the brown and black highly carbonaceous and argillaceous sandstone, which shows cross-limitation in places. Some of the depressions of the former land surface have been eroded to a depth of 6 feet below the adjoining elevations." Immediately above this eroded surface is the Lance formation, which Professor Leonard has described as "somber beds" and "lower Fort Union," with an estimated thickness of about 600 feet extending northward down the river 15 or 20 miles to the

* 5th Bienn. Rept. N. Dak. Geol. Surv., 1908, pp. 29-114.

† Op. cit., pl. v, p. 72.

neighborhood of Yule P. O. There is a very slight northward dip. Beds of carbonaceous shale and impure lignites are distributed throughout the formation beginning with the basal stratum, and in the upper half, according to Leonard, there are 5 or 6 workable coal beds. Dinosaur remains, including Triceratops and Trachodon, are not uncommon in the lower part, especially in the badlands near the mouth of Bacon Creek, a mile northeast of Marmarth. The formation is in every particular similar to the equivalent Lance formation in the Cheyenne River and Standing Rock reservations.

Irregular deposition and erosion with deep channeling are strikingly exhibited at several localities and on different horizons. One example of erosion which is worthy of description in a separate article is clearly shown in a cut bank by the side of the railroad yard at Marmarth, probably less than 100 feet above the base of the Lance formation. A bed of carbonaceous shale with an average thickness of 20 feet is exposed to its full length of 250 feet. Both the top and the bottom surfaces are irregular as if eroded, and the underlying sandstone and the argillaceous bands in the bed are filled with vertical roots of plants. One end of the bed fingers out into cross-bedded sand while the other end is abruptly truncated and abuts against a friable, cross-bedded yellowish gray sandstone similar to and continuous with the sand that overlies the carbonaceous bed. Here is evidence of erosion at the base of the carbonaceous bed apparently as great as that at the base of the whole formation, and of still greater erosion at the top of the same bed.

It will be noticed that in this area there is no brackish-water bed at the top of the Fox Hills. Instead the change is abrupt from marine to land or fresh-water deposits, but there is evidence that marine or at least brackish-water conditions continued in a neighboring area for some time after non-marine deposition began. Professor Leonard reported the finding of an oyster bed in the upper part of the "somber beds" about five miles southwest of Yule in sect. 16, T. 135 N., R. 105 W., which is only about 15 miles north of Marmarth. The locality was visited last summer and the oysters were found associated with a coal (apparently bed F of Leonard's section*) about 175 feet above the river level and according to Leonard's estimates approximately 500 feet above the base of the Lance formation and certainly above all the dinosaurs that have been found in the region. The abundant oysters referable to *Ostrea subtrigonalis* and *Ostrea glabra* lie a few feet above the coal in a carbonaceous shale. In some places the shells form a nearly solid band 6 inches thick, and they are distributed in thin bands and scattered individuals through 7 feet of shale. Such

* 5th Bienn. Rept. N. Dak. Geol. Surv., 1908, p. 78.

an oyster bed must have been formed in tidal waters connected with the sea, and its presence here argues strongly for the assumption that the underlying portion of the Lance formation was formed near sea level so that a slight downward movement permitted local temporary admission of brackish water into the low lying swamps and marshes in which coal was forming. It is, therefore, most probable that the abrupt change from marine to fresh-water and land conditions seen near Marmarth is purely local, and that the eroded surface at the top of the Fox Hills does not represent a time interval of any geologic importance.

Lance Creek Area, Converse County, Wyoming.

This well-known area has been described by Hatcher* and by Stanton and Knowlton,† and has recently been further discussed by Knowlton‡ and Stanton.§ In the examination of last summer special attention was given to the Fox Hills sandstone and its relation with the basal portion of the Lance formation. Our principal contribution to the knowledge of the stratigraphy of the area was the discovery that the marine Fox Hills deposits extend about 400 feet higher than had previously been determined, and that non-marine coal-forming conditions were temporarily inaugurated here before the close of Fox Hills time.

The first section examined is on the south side of Cheyenne River at the mouth of Lance Creek, and extending up the creek a mile and a half or two miles. Beginning at the top of a prominent white sandstone the section is as follows:

	Feet
1. White cross-bedded sandstone with irregular brown indurated bands, masses, and concretions	50
2. Soft sandy shale with bands of lignitic shale. Fragments of dinosaur bone were found on the surface here.....	50
3. Sandy shale full of <i>Corbicula cytheriformis?</i> and <i>Corbicula subelliptica</i> var. <i>moreauensis</i>	1/2-1
4. More or less carbonaceous shale.....	15
5. Soft massive gray sandstone with many brown concretions	25
6. Gray sandstone and sandy shale with bands of sandstone containing Fox Hills fossils, about	150
7. Cross-bedded, ripple marked, reddish brown sandstone with irregular base.....	8 to 10
8. Massive soft buff sandstone with many large concretions and indurated masses and an abundant Fox Hills fauna.	100
9. Pierre shale with only the top exposed.....	

* This Journal (3), vol. xlv, pp. 135-144, 1893. Am. Naturalist, vol. xxx, pp. 112-120, 1896. † Bull. Geol. Soc. Am., vol. viii, pp. 128-137, 1897.

‡ Proc. Washington Acad. Sci., vol. xi, pp. 179-238, 1909.

§ Ibid., pp. 239-293.

The following is the list of fossils collected in No. 8 of this section:

Avicula fibrosa M. & H.
Leda (*Yoldia*) sp.
Sphæriola? *cordata* M. & H.
Veniella humilis M. & H.
Protocardia subquadrata E. & S.
Linearia? *formosa* M. & H.
Tellina scitula M. & H.
Cuspidaria moreauensis (M. & H.)
Entalis paupercula M. & H.?
Lunatia occidentalis M. & H.
Anchura sp.
Fasciolaria (*Piestochilus*) *culbertsoni* M. & H.
Haminea sp.
Sphenodiscus lenticularis (Owen)
Scaphites conradi (Morton)
Scaphites conradi var. *intermedius* Meek.
Scaphites abyssinus (Morton).

No. 6 yielded the following:

Nucula planimarginata M. & H.
Avicula fibrosa M. & H.
Cardium speciosum M. & H.
Mactra warrenana M. & H.

When studying the section it was believed that the upper four members belong to the Lance formation, but afterward when comparison was made with sections at the south end of the field it seemed more probable that all the beds examined here belong to the Fox Hills. The higher unquestioned Lance formation was not studied at this place.

Two sections, which have been described by Stanton and Knowlton, were studied at the south end of the area, about 30 miles southwest of the mouth of Lance Creek. One of these lies about 2 miles east of Lance Creek, nearly opposite the mouth of Little Lightning Creek, and shows excellent exposures of Pierre, Fox Hills, and the lower part of the Lance formation, all dipping northward 14° to 19° . No attempt was made to obtain a detailed section of the Lance formation, but a measurement across the strike as far as the strata have steep dips shows a thickness of about 1700 feet above the upper white sandstone, which was later determined to be the top of the Fox Hills. To this should be added perhaps 400 or 500 feet for the thickness of the nearly horizontal upper strata of the Lance formation. The lowest point at which dinosaur bones were seen is about 300 feet above the top of the Fox Hills.

The lower part of the section is as follows:

Section on divide between Lightning and Buck Creeks.

	Feet
1. Gray sandstone	10
2. Shale	25
3. Sandstone and shale	20
4. Shale and coal	15
5. Shale with brackish-water fauna	20

Top of Fox Hills.

6. Massive white sandstone with brown concretions	40
7. Shaly sandstone	5
8. Coal and carbonaceous shale	15
9. Massive white sandstone	60
10. Shale	'8
11. Sandstone	10
12. Shale	5
13. Massive white sandstone	100
14. Brownish gray sandstone in alternations of massive and more thinly bedded	130
15. Gray sandstone	30
16. Brown sandstone	20
17. Yellowish sandstone with Fox Hills fauna	30
18. Pierre shale	

The last section examined and perhaps the best exposed and most instructive of all is on Johnson Brothers' ranch, near Buck Creek, about 8 miles east of the section just described. Beginning with the lowest strata of the Lance formation the section follows:

Section on Buck Creek.

	Feet
1. Sandy shale with thin beds of coal	25

Top of Fox Hills.

2. Massive white sandstone with <i>Halymenites major</i>	60
3. Yellowish massive sandstone with brown concretions ...	20
4. More thinly bedded brown sandstone with <i>Halymenites</i> ..	25
5. Massive white sandstone	75
6. Soft somewhat sandy shales with thin sandstone bands containing marine Fox Hills shells	30
7. Brown shaly sandstone	5
8. Massive white sandstone	60
9. Thin-bedded brown and gray sandstone	130
10. Yellowish massive sandstone with concretions containing Fox Hills fauna	100
11. Pierre shale	

The list of fossils from No. 6 is as follows:

Avicula nebrascana E. & S.

Avicula fibrosa M. & H.

Leda? sp.

Nucula planimarginata M. & H.

Tellina scitula M. & H.

Lamna? sp.

The occurrence of these fossils in No. 6 and of *Halymenites* at higher horizons shows that the strata to the top of the white sandstones are mainly marine and belong to the Fox Hills. In previous descriptions, only No. 10 was referred to the Fox Hills and the age of the overlying 400 feet of sandstones was left doubtful.

In the Lance Creek area the evidence for a gradual transition from the marine Fox Hills into the Lance formation is found in the occurrence of a brackish-water bed at the top of the marine strata, in the presence of coal beds and other evidence of alternating land and marine conditions before the close of the Fox Hills, and in the absence of any indication of an important unconformity anywhere in the section.

As compared with sections in the other areas here discussed the most striking feature of the Converse County sections is the much greater thickness of the Fox Hills sandstone and of the Lance formation. The average thickness of the Fox Hills sandstone in the South Dakota sections described is little more than 100 feet and it is still less at Marmarth, North Dakota, while in Converse County it is 400 to 500 feet, making the ratio about 1 to 4. The Lance formation shows about the same ratio of increase and the marine Cretaceous formations beneath the Fox Hills are also known to be much thicker in Converse County. Farther south in Colorado these marine formations, including the Fox Hills, show a still greater increase in thickness. It is therefore reasonable to attribute the variation in the thickness of the Fox Hills to variation in the rate of sedimentation due to varying distances from the source of supply and perhaps to variation in the height of the neighboring lands. That the varying thickness is not due to erosion from the top is proved in the case of some of the thinnest sections by the presence of the brackish-water beds at the top showing the final stage in marine sedimentation.

The three areas discussed in this paper taken together tell a story of gradually changing conditions near the end of the Cretaceous when the uplift of the Rocky Mountain region was draining the interior sea. The uplift was not uniform nor continuous and the emergence above sea level could not have been simultaneous for all localities throughout the region. As

the sea became shallow the effect of tidal currents and wave action was shown in irregular deposition, cross-bedding and local erosion, and when an area was elevated above tide the deposits formed were subjected to all the varying conditions of flood plains, deltas and marshes. It would depend on the configuration of the coast, the topography and drainage of the adjacent land and the rate of elevation whether at any particular locality the last marine bed would be covered by a brackish-water deposit or followed immediately by land conditions. With such a history it is not surprising that the Fox Hills sandstone varies considerably in thickness and shows somewhat varying relations with the overlying formation.

The bearing which the facts here presented have on the Laramie problem is self-evident. If it is true that there is a transition with practically continuous sedimentation from the Fox Hills sandstone into the Lance formation in the region discussed, then the Lance formation includes or forms part of the Laramie.

ART. XVII.—*A New Occurrence of Hydrogiobertite*; by
ROGER C. WELLS.

SOME specimens of an evaporation deposit which appear to consist chiefly of hydrogiobertite were recently examined in the chemical laboratory of the United States Geological Survey. These specimens were collected by Mr. G. A. Waring of the Survey in Chiles Valley, Napa Co., California, near Phillips Springs. The deposit occurs in considerable quantities below the springs and rests upon and penetrates a friable shale. In the vicinity above the springs are serpentinized rocks which may have been the source of the magnesium. In one specimen the incrustation covers fossil wood; in other specimens the surface of the shale is covered by spherulitic growths of 1-2^{mm} diameter, while the interstices of the shale are completely filled with the deposit.

Examined under the microscope, the spherules are seen to possess a banded structure, and to contain small amounts of a white opaque substance. Under these circumstances, an exact optical characterization could not easily be made. The spherules are white externally, their broken surfaces grayish-brown. $G_{24^\circ} = 2.152$ (Thoulet solution). $H. = 3-4$. Streak white. The substance effervesces with cold acid. Many of the spherules contain a particle of shale in the center.

Two samples of the incrustation were analyzed. The first, A, was powdered as submitted, including considerable shale; the second, B, a small portion, had been picked as free from the shale as possible. The results of two analyses of A and of B are given in the first three columns. In the next two columns are given the percentage of MgO , CO_2 and H_2O , reduced to 100 per cent after subtracting the CO_2 equivalent to the CaO found. In the last column is given the theoretical percentage for hydrogiobertite, $2MgO.CO_2.3H_2O$.

	A1	A2	B	Mean of A1 and A2	B	Theory
Insoluble .	25.41	25.33	14.93			
$(Al,Fe)_2O_3$.	1.85	1.90	1.06			
CaO -----	2.54	2.60	1.84			
MgO -----	-----	31.81	36.40	46.94	45.80	44.9
CO_2 -----	18.08	18.06	23.71	23.64	28.00	24.7
H_2O -----	19.81	20.06	20.81	29.42	26.20	30.4
		99.76	98.75	100.00	100.00	100.0

The original hydrogiobertite described by Scacchi was found in an igneous rock.* Later, a mineral provisionally designated

* E. Scacchi, Rend. Accad. Sci. Napoli, Dec. 12, 1885.

hydrogiobertite was found on asbestos by Brugnatelli in the Val Brutta.* The same author subsequently examined a similar mineral more thoroughly and designated it artinite with the formula $\text{MgCO}_3 \cdot \text{Mg}(\text{OH})_2 \cdot 3\text{H}_2\text{O}$.† The deposit here described seems to agree better with the formula of hydrogiobertite than with that of any other hydrated basic carbonate of magnesium. The occurrence is remarkable for being a spring deposit. As might be expected under these conditions, the specimens are not very pure and vary considerably from point to point. The deposits are freely exposed to the weather and rain, which may partly account for their irregularity of growth and structure.

U. S. Geological Survey, June 15, 1910.

* Zs. Kryst., xxxi, 54, 1899.

† Zs. Kryst., xl, 103, 1905, xli, 257, 1906.

ART. XVIII.—*A New Occurrence of Plumbojarosite*; by
W. F. HILLEBRAND and FRED. E. WRIGHT.

SOME months ago the senior author received from Prof. O. C. Farrington, of the Field Museum of Natural History, Chicago, a small sample of what was supposed to be jarosite. It had been received some years before from Dr. Merrill of the Utah School of Mines, who said that it came from American Fork, Utah. It formed friable lumps in association with pyromorphite and calcite for the most part. These two were easily removed by dilute nitric acid, and treatment with the Thoulet solution freed the mineral nearly completely from a further impurity of relatively low density. Analysis gave the following values for the constituents:

Fe_2O_3	42.87*	per cent.
PbO	18.46	"
K_2O	0.15	"
Na_2O	0.52	"
SO_3	27.67	"
H_2O	10.14	"
CuO	0.10	"
CaO	0.06	"
Insol.	0.40	"
100.37		

* With a very little P_2O_5 . Alumina probably absent.

The analysis had to be made in odd moments and is, therefore, not so satisfactory in all respects as could be wished, but the agreement with the analysis of plumbojarosite from Cook's Peak, New Mexico,† is most striking.

Crystallographic and Optical Properties.—The crystals are small and average about 0.15^{mm} in width and 0.05 to 0.1^{mm} in thickness. They occur in sharply bounded, equant hexagonal plates, limited by the basal pinacoid c (0001) and the unit rhombohedron r ($10\bar{1}1$). Under the microscope the minute crystals occasionally resemble in shape a spinel crystal resting on an octahedral face. Several of the crystals were measured on the two-circled goniometer with reducing attachment. For the adjustment the rhombohedral faces, and not the base, which invariably gave multiple reflection signals, were used. The angular values obtained varied slightly from crystal to crystal, but this was probably chiefly, if not wholly, due to the poor quality of reflection signals obtained. On one crystal 0.21^{mm} wide and 0.08^{mm} thick, the average of the angles ρ , or $c \wedge r$, for

† This Journal (4), xiv, 213–215, 1902.

the three unit rhombohedral faces was $53^{\circ} 41'$, while on a second crystal a slightly lower average value, $53^{\circ} 15'$, was obtained. So far as can be judged from the measurements made, the most probably value is about $53^{\circ} 40'$, a value which may possibly be in error $20'-30'$.^{*} This value is a little lower than that obtained by Penfield† on plumbojarosite from Cook's Peak, New Mexico ($c:r=54^{\circ} 30'$), and part of the difference may be due to difference in chemical composition, and part to uncertainty in angular measurements as a result of the imperfect development of the crystal faces. In habit, the crystals from Utah differ also slightly from those in New Mexico, the latter crystallizing in thin flakes, while the former, although tabular in shape, are much thicker and more nearly equant.

In the aggregate the deep brownish red crystals glisten with almost adamantine luster. They are brittle and easily crushed, and in powder form give an ochre-colored streak. Evidences of fair cleavage after the unit rhombohedron ($10\bar{1}1$) were observed.

Under the microscope the grains are pale golden yellow to brownish red in color and strongly pleochroic, c being dark brownish red and a pale golden yellow. Absorption strong $c > a$.

The refraction indices are high and were determined by the immersion method; ϵ is about 1.785 and $\omega > 1.825$. The birefringence is strong and greater than $.040$. In convergent polarized light, the crystals are uniaxial, optically negative, with strong birefringence. Occasionally a slight opening of the dark interference cross was observed but was not of sufficient regularity in its occurrence to be significant.

Washington, D. C.
July 1.

^{*} This angle $c:r$ was also determined by Dr. O. C. Farrington (letter of July 6, 1910). His measurements averaged $53^{\circ} 30'$, a value which agrees fairly well with the above.

† This Journal (4), xiv, 213-215, 1902.

ART. XIX.—*The Heat of Formation of the Oxides of Cobalt and Nickel; and sixth paper on the Heat of Combination of Acidic Oxides with Sodium Oxide; by W. G. MIXTER.*

[Contributions from the Sheffield Chemical Laboratory of Yale University.]

Cobalt.

1. *Heat of combustion of cobalt*—The cobalt and its oxides used in the work were obtained from a cobalt carbonate of unknown source. It was probably made by precipitation with ammonium carbonate, as it contained ammonia. Metallic cobalt, which was reduced by hydrogen at about 420° and kept at this temperature for three hours and at a pressure of 65^{mm} of mercury and then left to cool, ignited spontaneously in the air. When the reduction was made at incipient redness, then lowering the temperature to 420° and reducing the pressure as above stated, the oxidation was less rapid in air. The metal reduced at 420° was dark grey and very bulky; that reduced at the higher temperature was lighter colored. Whether oxidation of the cobalt at common temperature was due to the finely divided state of the metal or to a content of hydrogen was not determined. The metal used for the calorimetric experiments was reduced at a cherry-red heat and cooled in hydrogen at atmospheric pressure. It probably oxidized slightly in the air. It was sifted through a $1/100$ inch mesh. The method of determining the heat of oxidation of cobalt was as follows: The metal was spread over a flat, thin silver foil or mica tray 7 to 8^{cm} in diameter, which was fastened 3 to 6^{cm} above the bottom of the bomb. The bomb was exhausted and then filled with dry oxygen at a pressure of 12 to 13 atmospheres. In the upper half of the bomb was a fine iron wire which was ignited by an electric current. The hot globule of magnetic oxide falling on the cobalt ignited it. The tray, the oxide formed and the unoxidized cobalt were all melted. The oxide was found in the bottom of the bomb in the shape of a black crystalline hollow lump about 3^{cm} wide and 2^{cm} thick. The unburned metal was in one or more globules at the bottom of it. The observed weight of the solid contents of the lower half of the bomb less the weight of the tray, metal taken and Fe_3O_4 from the iron wire, plus 4.4 per cent correction for water and volatile matter in the mica, gave the weight of oxygen taken up in the combustion. After weighing, the lump above mentioned was broken and the globules of metallic cobalt separated and weighed. To make sure that the oxide was then free from particles of the metal it was pulverized and

stirred up in water with an electromagnet. The weight was noted of the metallic cobalt found in a fusion.

Experiment 1.—The platinum electrode in the bomb was a millimeter thick and was about 3^{cm} above the tray. The end of it melted off at the time of the combustion and dropped into the mass below and alloyed with the cobalt. Hence the gain in weight due to oxygen could not be found and, therefore, the oxide was reduced by hydrogen. The loss in oxygen was 2.747 grams. The calorimetric result, $9658^{\circ} \div 2.747 = 3480^{\circ}$ for 1 gram of oxygen taken up and for 16 grams 55,680°.

Experiment 2.—This test was like the preceding except that a mica tray was used. It was placed lower in the bomb and farther from the platinum electrode, which, nevertheless, melted off. The cobalt oxide was reduced as before. The result for 16 grams of oxygen was 55.984°.

Experiments	3	4	5
Cobalt.....	12.417 grams	13.027 grams	15.364 grams
Cobalt unburned....	0.793 “	0.507 “	1.631 “
“ burned.....	11.624 “	12.520 “	13.733 “
Mica tray.....	0.417 “	0.497 “	0.268 “
Oxygen taken up ...	3.088 “	3.340 “	3.706 “
Water equivalent of system.....	3,467 “	3,535 “	3,617 “
Temperature interval	3.190°	3.396°	3.678°
Heat effect.....	11,060	12,005	13,303°
“ of oxidation of iron	50	48	50°
	11,010	11,957	13,253°
For 1 gram of oxygen.....	3,565	3,580	3,576°
“ 1 “ “ cobalt.....	947	955	966°
“ 16 “ “ oxygen.....	57,040	57,280	57,216°
“ 59 “ “ cobalt.....	55,873°	56,345°	56,994°
Oxygen ratio	$\frac{3.088}{16} = 0.193$	$\frac{3.34}{16} = 0.209$	$\frac{3.706}{16} = 0.232$
Cobalt ratio..	$\frac{11.624}{59} = 0.197$	$\frac{12.52}{59} = 0.212$	$\frac{13.733}{59} = 0.233$

In 3 all of the metallic cobalt left was in one globule. The oxide obtained in this experiment was pulverized in a steel mortar and the powder stirred up in water with an electromagnet which removed an insignificant quantity of black particles. Next, 2.8969 grams of the powdered oxide, dried at 100°, was reduced by hydrogen, and 2.2800 grams or 78.74 per cent of cobalt obtained. CoO contains 78.67 and Co₃O₄

73.44 per cent of cobalt. The cobalt was not quite pure, containing a little silicon and iron. The ratio of oxygen consumed to cobalt burned in experiments 3, 4, and 5 and the ratio found in the analysis given is very nearly 1 to 1, proving that the oxide is mostly CoO . Portions of oxide from the combustion were tested for a higher oxide by treating with hydrochloric acid. A small quantity of chlorine evolved indicated that the oxide contained a little Co_3O_4 . Why then is not the ratio of oxygen to cobalt greater than 1 to 1 instead of slightly less? The presence of impurities accounts for it in the portion analyzed, and the fact that the oxygen ratios found in experiments 3, 4, and 5 are low, and also that the heat effect calculated for one gram atom of cobalt burned is less than found for one gram atom of oxygen taken up, prove that the cobalt used in the experiments was slightly oxidized. Moreover, the formation of a small amount of Co_3O_4 affects the result but slightly since, as shown later, $3\text{CoO} + \text{O} = \text{Co}_3\text{O}_4 + 41,700^\circ$.

The result, therefore, based on the oxygen consumed should be regarded as the better one. The average of the results is $57,179^\circ$ at constant volume and $57,460^\circ$ at constant pressure for the heat effect of 16 grams of oxygen combining with cobalt to form chiefly crystalline cobaltous oxide. Dulong* made one determination of the heat of combustion of cobalt and found that 1 liter of oxygen combining with cobalt gave a heat effect of 5721° . For 16 grams of oxygen the result is $64,000^\circ$.

Cobaltous oxide in a finely divided and amorphous form oxidizes readily when heated in air to Co_3O_4 , and Foote and Smith† have shown that the dissociation pressure of the latter oxide is 10^{mm} at 800° , the pressure rising rapidly with increasing temperature. These facts explain the formation of CoO when cobalt is burned in oxygen under pressure. The high temperature accompanying the reaction dissociates any Co_3O_4 formed into CoO and O and the molten CoO falling upon the cold bomb is quickly changed to a solid which as it cools takes up oxygen only on its surface. The following experiment shows the slow rate of oxidation: 1.1424 gram of finely pulverized cobaltous oxide of same lot taken for the analysis on p. 194 gained on heating to redness for 15 minutes in oxygen 0.0267, after 3 hours heating in air 0.0030, and then gained 0.0035 gram when heated an hour in oxygen. The total gain was 0.0332 gram; the calculated gain for complete oxidation to Co_3O_4 being 0.0812 gram.

2. Heat of reaction of cobalt with sodium peroxide. Experiments 6 and 7.—Cobalt 4.000, sulphur 1.000, sodium

* C. R., xii, 871, 1838.

† J. Am. Chem. Soc., xxx, 1344.

peroxide 20 grams. Thermal effect for 1 gram of cobalt 1039° and 1040°. For 59 grams, 61,360°.

The fusions disintegrated slowly in cold water with evolution of oxygen. The insoluble black residue contained sodium, water and a peroxide.

3. *Heat of reaction of cobaltous-cobaltic oxide with sodium peroxide.*—Cobaltous-cobaltic oxide, prepared from carbonate by heating in air, yielded very nearly the theoretical amount of metal when reduced by hydrogen. It was in the form of a bulky powder.

Experiment 8.—Cobaltous-cobaltic oxide 6.000, sulphur 1.000, sodium peroxide 15 grams. Heat effect of 1 gram Co_3O_4 286°.

Experiment 9.—Cobaltous-cobaltic oxide 9.000, sulphur 1.500, sodium peroxide 22 grams. Heat effect of 1 gram Co_3O_4 282°.

The fusions were good and gave off much oxygen when placed in cold water. The black residue left by water retained alkali after prolonged digestion and washing with water. After remaining for several days in a vacuum over sulphuric acid it was found to yield water and oxygen when heated. The average of the two results is 284°. For a gram molecule of Co_3O_4 it is 68,444°.

4. *Heat of reaction of cobaltous oxide with sodium peroxide.*—Amorphous cobaltous oxide was prepared by heating the carbonate in a current of dry carbon dioxide. The following are the experiments:

Experiment 10.—Cobaltous oxide 8.000, sulphur 1.000, sodium peroxide 18 grams. Heat effect of 1 gram cobaltous oxide 394°.

Experiment 11.—Cobaltous oxide 10.266, sulphur 1.000, sodium peroxide 21 grams. Heat effect of 1 gram of cobaltous oxide 414°.

The average of the two results, $404^\circ \times 75 = 30,390^\circ$.

Summary of Results on Cobalt.

$\text{Co} + \text{O} = \text{CoO (crystalline)} +$	-----	57.5°
$\text{Co} + \text{O} = \text{CoO (amorphous)} +$	-----	50.5°
$3\text{Co} + 4\text{O} = \text{Co}_3\text{O}_4 +$	-----	193.4°
$3\text{CoO (amor.)} + \text{O} = \text{Co}_3\text{O}_4 +$	-----	41.9°
$\text{Co} + 2\text{Na}_2\text{O}_2 = \text{Na}_2\text{CoO}_3 + \text{Na}_2\text{O} +$	-----	61.4°
$2\text{Na}_2\text{O} + 2\text{O} = 2\text{Na}_2\text{O}_2 +$	-----	38.8°
$\text{Co} + 2\text{O} + \text{Na}_2\text{O} = \text{Na}_2\text{CoO}_3 +$	-----	100.2°
$\text{Co}_3\text{O}_4 + 2\text{Na}_2\text{O}_2 + \text{Na}_2\text{O} = 3\text{Na}_2\text{CoO}_3 +$	-----	68.4°
$2\text{Na}_2\text{O} + 2\text{O} = 2\text{Na}_2\text{O}_2 +$	-----	38.8°
$\text{Co}_3\text{O}_4 + 2\text{O} + 3\text{Na}_2\text{O} = 3\text{Na}_2\text{CoO}_3 +$	-----	107.2°

CoO (amor.) + Na ₂ O ₂ = Na ₂ CoO ₃ + ...	30·3°
Na ₂ O + O = Na ₂ O ₂ + ...	19·4°
CoO + O + Na ₂ O = Na ₂ CoO ₃ + ...	49·7°
Co + 2O + Na ₂ O = Na ₂ CoO ₃ + ...	100·2°
CoO + O + Na ₂ O = Na ₂ CoO ₃ + ...	49·7°
Co + O = CoO (amorphous) + ...	50·5°
3(Co + 2O + Na ₂ O) = 3Na ₂ CoO ₃ + ...	300·6°
Co ₃ O ₄ + 2O + 3Na ₂ O = 3Na ₂ CoO ₃ + ...	107·2°
3Co + 4O = Co ₃ O ₄ + ...	193·4°

Sodium cobaltite, Na₂CoO₃, has not been isolated, but very probably is formed in the fusions where there is an excess of sodium peroxide because cobaltites of other metals exist, as for example BaCoO₃, and MgCoO₃. Whether Na₂CoO₃ is formed in the fusion or some other sodium cobaltite makes no difference in the heat of oxidation derived, since the same cobaltite is formed in the fusions containing either cobalt or a cobalt oxide.

The heat effect of Na₂O + CoO₂ cannot be derived from the results, since the heat of formation of CoO₂ is not known. It is, however, 7·8° or greater. Assuming that one atom of oxygen combining with CoO gives the same heat effect as when combining with 3CoO, we have

	Co + 2O = 50·5 + 41·9 = 92·4°	
and	Co + 2O + Na ₂ O = Na ₂ O CoO ₂ + ...	100·2°
	Co + 2O = CoO ₂ + ...	92·4° ?
	Na ₂ O = CoO = Na ₂ O CoO ₂ + ...	7·8° ?

Nickel.

Two preparations of nickel were made from nickel carbonate from the J. T. Baker Chemical Company by converting it into oxide and then reducing with hydrogen. The preparation designated as *a* was reduced at a bright red heat. The nickel obtained was light gray and coherent. It was pulverized and sifted through 1/50 inch mesh. When burned in air it yielded only a trace of water, showing it to contain too little hydrogen to affect the calorimetric results. Another reduction was made (*b*) at a temperature of approximately 510°, and when it was complete the hydrogen was pumped out until the pressure fell to 30^{mm}. The apparatus containing the metal was then left to cool. When it was poured into a bottle oxidation took place

so rapidly that the temperature of the metal rose 30° . The metal, marked *b*, was darker colored and more voluminous than *a*.

5. *Heat of combustion of nickel.*—The following are the experiments:

	1	2	3	4	
Nickel	12.000 (<i>a</i>)	18.003 (<i>b</i>)	22.099 (<i>b</i>)	16.000	grams (<i>a</i>)
Mica tray	0.576	0.677			
Silver tray			3.1245	3.188	"
Oxygen taken up....	2.127	3.527	3.789	2.557	"
Water equivalent of system	3,568.	3,666.	3,647.	3,674.	"
Temperature interval.	2.183°	3.470°	3.735°	2.508°	
Heat effect	7,789	12,721	13,622	9,214	$^{\circ}$
" of oxidation given	—48	—50	50	50	$^{\circ}$
	7,741	12,671	13,572	9,164	$^{\circ}$
For 1 gram of oxygen..	3,640 $^{\circ}$	3,593 $^{\circ}$	3,582 $^{\circ}$	3,584 $^{\circ}$	

The average is 3600° for 1 gram of oxygen combining with nickel. For 16 grams it is $57,600^{\circ}$ at constant volume and $57,900^{\circ}$ at constant pressure.

The product of a combustion was a sintered mass having the shape of the layer of metal burned. The trays holding the nickel were in all cases melted, the mica forming a slag adhering to the nickel oxide and the silver falling away from it. It was impossible to separate the metal from the oxide by a magnet as the two were so intimately mixed. In one trial an electromagnet removed $5/6$ of the pulverized material from water. The product of experiment 4, in which a silver tray was used, contained a few black vitreous pieces which were also magnetic. Small globules of nickel were also present, showing that temperature of the combustion was high. The metal oxidized in experiment 1 was 65 per cent of the amount present; in 2, 75 per cent; in 3, 63 per cent; and 4, 59 per cent. The calculations are based on the oxygen taken up to form NiO , and there is no good reason for supposing that a lower oxide was formed.

The heat of oxidation of cobalt has been regarded as a little greater than that of nickel as indicated by Thomsen's results, which are $\text{Co}_2\text{O}_3, \text{H}_2\text{O} = 63,400^{\circ}$, and $\text{Ni}_2\text{O}_3, \text{H}_2\text{O} = 60,840^{\circ}$. Dulong's results* are of the same order, namely, $\text{Co}_2\text{O}_3 = 64,000^{\circ}$ and $\text{Ni}_2\text{O}_3 = 59,700^{\circ}$, each, however, from a single experiment found after his death recorded in his note-book.

* Loc. cit.

The writer's results, on the contrary, are practically alike, thus: $\text{Co} + \text{O} = \text{CoO}(\text{crystalline}) + 57,400^\circ$ and $\text{Ni}_2 + \text{O} = \text{Ni}_2\text{O} + 57,900^\circ$. As the nickelous oxide was sintered together and partly fused, it is compared with crystalline cobaltous oxide and not the amorphous form.

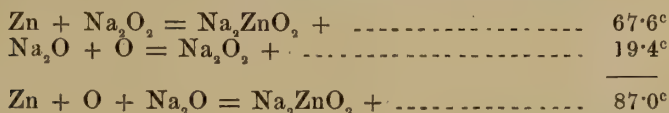
Nickel does not burn well enough with sodium peroxide to give a satisfactory result. The amorphous nickelous oxide is more finely divided than the metal and appears to burn better, but it is impossible to interpret a thermal result without other data.

Zinc.

6. *Heat of reaction of zinc with sodium peroxide.*—Zinc powder free from oxide was made by chipping off the metal on a lathe with a flexible chisel. A mixture of the powder and sodium peroxide burns when ignited by a hot wire with explosive violence and in a bomb yields a fused mass. Three combustions were made with the following mixtures:

	1	2	3
Zinc taken	8.010	10.575	10.580 grams
“ not oxidized	0.072	0.054	0.047 “
“ oxidized	7.938	10.521	10.533 “
Sodium peroxide	10.	15.	15. “
Heat effect of 1 gram of zinc	1,021°	1,048°	1,033°

The mean, $1033 \times 65.4 = 67,600^\circ$ from which the heat of formation of sodium zincate is derived, is as follows:



DeForcrand* prepared compounds which may be regarded as hydrated peroxides of zinc or zinc oxide and hydrogen peroxide, as for example $\text{Zn}_3\text{O}_5 + 2\text{H}_2\text{O}$ or $3\text{ZnO} + 2\text{H}_2\text{O}_2$. Hence the question—Was a peroxide formed in the fusions described? Evidently not, since in experiment 1 9.4 grams of sodium peroxide were required to form zinc oxide, and in 2 and 3, 12.6 grams.

DeForcrand† calculated the heat of formation of zinc oxide from the observations of other investigators, taking the atomic weight of zinc as 65, and obtained the following:

* Ann. de Chem. et Phys. [7], xxvii, 26.

† Loc. cit.

Dulong	84·37°
Andrews	87·20
Favre and Silbermann	{ 84·04
	{ 82·88
Murignac	85·23
	{ 88·16
Ditte	{ 87·73
	{ 85·46
	{ 83·22

The mean is 85·06°. DeForcrand found for ZnO prepared at 125° 82·97° and for oxide made at the temperature of burning zinc 84·7°. Ditte also worked with preparations of zinc oxide which had been subjected to different temperatures. The results of the two investigators are essentially 83·0° for zinc oxide prepared at a low temperature. Since the combustion of zinc with sodium peroxide gives only 87·0° it is evident that the heat effect of $\text{Na}_2\text{O} + \text{ZnO}$ is very small, only 4·0 large calories.

Manganese.

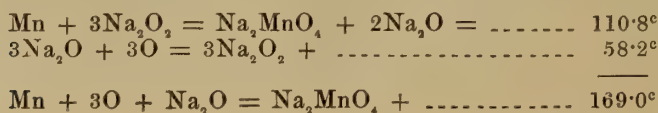
7. *Heat of reaction of manganese with sodium peroxide.*—Manganese for the work was prepared by the Goldschmidt method. It was free from aluminum and contained a trace of silicon. Three combustions of the following mixtures were made:

	1	2	3	
Manganese	3·000	5·000	5·116	grams
Sulphur	1·000	1·000	0·500	"
Sodium peroxide	17·	30·	30·	"

Result for 1 gram of manganese.. 2237° 2043° 1985°

The fusions were green. Number 1 gave little gas when placed in water, the other two considerable gas. The solutions of all were green and much brown powder remained. In 1 the amount of sodium peroxide used was not sufficient to oxidize all of the manganese to MnO_3 , and since the result is higher than the others the inference is that MnO_3 is formed from MnO_2 with absorption of heat.

The mean of the second and third results is 2014° and for 55 grams of manganese it is 110,770°. Hence, for the heat of the oxidation of manganese to MnO_3 plus the combination of the trioxide with sodium oxide we have



8. *Heat of reaction of manganese dioxide with sodium peroxide.*—Manganese dioxide was prepared by heating manganese nitrate until the residue ceased to lose weight at 400° . A weighed amount of the dioxide left on ignition very nearly the calculated quantity of Mn_2O_3 .

Combustions of the following mixtures were made :

Manganese dioxide	8.000	10.000 grams
Sulphur	1.000	1.000 “
Sodium peroxide	19.	21. “
Result for 1 gram of MnO_2	368°	323°

The mean is 345° and for a gram molecule of manganese dioxide it is 30.0° , adding 19.4° for the heat of $\text{Na}_2\text{O} + \text{O}$ gives for $\text{MnO}_2 + \text{O} + \text{Na}_2\text{O} = \text{Na}_2\text{MnO}_4 + 49.4^{\circ}$.

For the heat effect of $\text{Mn} + 2\text{O}$ we have $169.0^{\circ} - 49.4^{\circ} = 119.6^{\circ}$. As the experiments do not show that Mn and MnO_2 are completely oxidized in the fusion to MnO_3 the results are to be regarded as approximations. The errors cannot be large since Le Chateliers* found that $\text{Mn} + 2\text{O} = \text{MnO}_2$ (crystalline) $+ 126.0^{\circ}$ or 6.4° more than given above for amorphous MnO_2 ; and the heat of formation of an amorphous compound is always less than that of the crystalline form. Manganese trioxide decomposes at common temperature into the dioxide and oxygen. This spontaneous change indicates that the reaction $\text{MnO}_2 + \text{O}$ is endothermic, at least it is not exothermic. The heat effect of $\text{MnO}_2, \text{O}, \text{Na}_2\text{O} = 49.4^{\circ}$ results chiefly from the reaction $\text{Na}_2\text{O} + \text{MnO}_3$.

* C. R., cxxii, 81.

ART. XX.—*Mosesite, a New Mercury Mineral from Terlingua, Texas*; by F. A. CANFIELD, W. F. HILLEBRAND, and W. T. SCHALLER.

Introduction.

THE name *mosesite* is proposed for a new mercury mineral from Terlingua, Brewster Co., Texas, in honor of Prof. Alfred J. Moses of Columbia University, New York, who first definitely described the interesting mercury minerals found in Texas. The three minerals, montroydite, terlinguaite and eglestonite, were named and definitely determined by him, and he also gave a preliminary notice of a fourth new one (later named kleinite). It is, therefore, with great pleasure on our part that we propose the name *mosesite*, which name, besides perpetuating the high attainments of Professor Moses in the science of mineralogy, is particularly appropriate as it links his name with a group of minerals which he first definitely put on record.

General Description (F. A. Canfield).

While examining a recently acquired specimen of montroydite and calcite the attention of the writer was attracted to some small yellow crystals which were perched upon the crystals of calcite. They did not join the montroydite but were isolated and solitary; they appeared to lie upon the surface of the calcite with but little or no bond. The slightest touch would loosen them, leaving no scar upon the calcite but merely a clean spot. A careful search revealed twenty-six crystals which will weigh, perhaps, ten milligrams. Twenty-two of the crystals are simple octahedrons, the others are spinel twins. No other forms were observed and none of the mineral was massive.

Another specimen has lately been procured which is much the finer in every way. Hundreds of crystals are scattered over a surface ($4^{\text{cm}} \times 6^{\text{cm}}$) of calcite which rests upon the pinkish rock which is characteristic of the Terlingua specimens. Nearly all of the crystals are spinel twins. They are frequently grouped together in confused masses; one polysynthetic twin—a 5-ling—was seen. Simple octahedrons are rare. None was modified by other forms. No other mercury mineral is present on the specimen unless some delicate, elongated, light yellow particles should prove to be kleinite.

It is impossible to tell to what conditions these specimens have been subjected. It is certain that the first specimen has been badly treated, since it is bruised and very dusty.

There are no indications that the crystals are affected by the light. If light affects the color it must act very slowly. The color of those crystals, which are so situated as to have some protection from the light, is exactly like that of the most exposed. No difference in color could be noted between the surface and the interior of the crystals. Most of the crystals are translucent. The largest crystal found is brilliant and transparent, and measures 0.5^{mm} along its edge. Generally the faces of the crystals are bright and uneven. They are very brittle with signs of cleavage.* The fracture is uneven. The hardness slightly exceeds that of calcite. The mineral crumbles to a powder under the pressure required for this test. No piece could be obtained that was large enough to determine the density. The luster is adamantine. The color is a rich lemon- to a canary-yellow. The streak and powder are a very pale yellow.

When heated gradually to a low temperature in a closed tube the assay turns to a dark reddish brown, almost black. As the heat increases the color changes rapidly to white, but without changing the form of the original crystals. Fumes of calomel are given off and condense in the tube. Many globules of mercury collect in the tube beyond the coating of calomel. Continued heating soon causes the assay to volatilize and disappear. If a fresh fragment of the mineral is heated rapidly in the closed tube, it decrepitates violently, almost explosively, then it fuses and volatilizes.

In cold hydrochloric acid the mineral is changed slowly to a white substance which retains the original form. If the acid is hot the change is more rapid but the product is the same.

It is to be hoped that enough of the material will be found to enable a complete analysis to be made. No doubt there are specimens of this mineral in some of the collections, but they are overlooked, or they are incorrectly labeled. The second of the above-described specimens was labeled "Terlinguaite." It is more like kleinite in appearance.

Chemistry (W. F. Hillebrand).

Chemically, so far as the very scanty material permitted of ascertaining, the composition of mosesite approaches that of kleinite, that is, it is a mercury-ammonium compound containing chlorine and the sulphate group besides a little water. Determinations made on 0.04 gram of material gave 5 per cent Cl and 3.5 per cent SO_4 . The former amount is considerably lower and the latter somewhat higher than in kleinite, but the

* Imperfect octahedral cleavage (W. T. S.).

values are no more than approximations. There is, however, one marked chemical difference, which will be considered later.

Spectroscopic tests, that were kindly made by Dr. P. G. Nutting, at the Bureau of Standards, showed prominent mercury and nitrogen spectra and also the red line of hydrogen, the last being ascribed by him to water vapor. A singular feature of the behavior in vacuo was the immediate appearance, when the current was turned on and before the application of heat, of a mercury spectrum. The mineral was at the time not between the electrodes, but far to the rear of one of them, at the sealed end of the Plucker tube. Under these conditions the color of the mineral fragments underwent a pronounced and permanent change from bright yellow to a yellowish gray. With a minute crystal of kleinite there was a mere indication of the mercury lines before heating, and no color change was observed. As soon as the temperature of mosesite was raised to visible incipient decomposition, the spectra of both nitrogen and mercury became brilliant. As mentioned by Mr. Canfield, mosesite does not seem to undergo the color changes in sunlight and darkness that appear to be characteristic of the deeper colored crystals of kleinite.

When heated in a narrow tube closed at one end, the color changes and the sublimates were much like those afforded by kleinite, and there was the same liberation of an active gas that set free iodine from potassium iodide. Ammonium bromide liberated ammonia as from kleinite.

The behavior towards hydrochloric acid, noticed by Mr. Canfield, affords a certain chemical means of distinguishing mosesite from kleinite, where only these two are concerned. When covered with concentrated hydrochloric acid mosesite is entirely decomposed in a few hours, with separation of a coherent white material that shows the behavior of calomel. The solution contains the sulphate and ammonium groups, beside much mercuric mercury. Kleinite, on the other hand, shows no perceptible change for a long time, but in the course of 48 hours a minute crystal of it was almost entirely decomposed. There remained only a whitish residue that looked as if it might be the clay matter that is such a persistent contaminant of the mineral. It was free from calomel.

It will be remembered that the chemical evidence points to kleinite being a mixture or solution of mercury-ammonium chloride with a mercuric sulphate and perhaps chloride. There would seem to be an association of similar general character in mosesite, but with a mercurous sulphate or chloride replacing in part or wholly the corresponding mercuric salts of kleinite.

Crystallography and Optical Properties (W. T. Schaller).

The crystals are apparently octahedra of the isometric system. Twinning on the spinel law has been observed several times, in which case the crystals of mosesite are often flattened parallel to a pair of octahedral faces. Mr. Canfield has mentioned a 5-ling, a spinel twin repeated five times.

The faces of the crystals are never smooth. While bright and often highly polished, they are uneven and only a few of the faces give a single reflection. Most of the faces when measured on the goniometer give a number of signals, no particular one of which is brighter than the others. This has rendered the accurate determination of the form of the crystals impossible. An additional feature that has rendered accurate measurements difficult is the tendency for a number of crystals to grow together, sometimes in nearly parallel position and again in widely different positions. A mass of signals therefore resulted from examining such groups of mosesite on the goniometer, and on the minute crystals that were available it was not possible to know what signals to measure and what ones to exclude. Where only two or three faces were measured in a zone, it was well nigh impossible to be sure of having the zone accurately centered. The measurements, the occurrence of (probable) spinel twins and the optical relations, to be described below, make it fairly certain that the crystals of mosesite are in reality octahedra. No form other than the octahedron was observed.

On part of a spinel twin, the faces of which gave a mass of very poor reflections, there were measured :

$o \wedge o'$	$\left\{ \begin{array}{l} = 68^\circ \text{ ----- } 70^\circ 32' \text{ calc.} \\ = 68^\circ \text{ (cleavage face) ----- } \text{ " } \text{ " } \\ = 68^\circ 28' \text{ ----- } \text{ " } \text{ " } \end{array} \right.$
$o \wedge \underline{o}$	$= 41^\circ 13' \text{ ----- } 38^\circ 56' \text{ "}$

A second crystal, also a spinel twin, gave :

$o \wedge o'$	$\left\{ \begin{array}{l} = 108^\circ 54' \text{ ----- } 109^\circ 28' \text{ calc.} \\ = 107^\circ 53' \text{ ----- } \text{ " } \text{ " } \\ = 71^\circ 38' \text{ ----- } 70^\circ 32' \text{ " } \\ = 70^\circ 47' \text{ ----- } \text{ " } \text{ " } \\ = 68^\circ 51' \text{ ----- } \text{ " } \text{ " } \\ = 72^\circ 28' \text{ ----- } \text{ " } \text{ " } \end{array} \right.$
$o \wedge \underline{o}$	$\left\{ \begin{array}{l} = 37^\circ 06' \text{ ----- } 38^\circ 56' \text{ " } \\ = 38^\circ 56' \text{ ----- } \text{ " } \text{ " } \end{array} \right.$

A third crystal was adjusted as closely as possible in polar position for two-circle measurement and on revolving the

crystal, the four octahedra faces were seen to lie in the positions required for the form (111).

From the above data, meager and poor as they are, the isometric character of the crystals is deduced, especially as this is supported by the investigation of the optical properties.

Under the microscope mosesite is pale yellow, non-pleochroic and seems to possess a rather low double refraction. When a fragment is crushed many of the resultant pieces show the octahedral cleavage, either in their triangular or rhombic shape (when only two directions of cleavage are developed) or in three series of cleavage lines, parallel to the octahedral faces. A fragment of fluorite was crushed and examined under the microscope, when similar effects were seen, though in this case the cleavage was much better developed.

The crystallographic investigation has shown that the crystals are in all probability isometric octahedra and should, therefore, be isotropic when examined under the microscope with crossed nicols. Such an examination, however, shows the mineral not to be isotropic but doubly refracting. On heating the mineral to 186° , the crystals lose their double refraction and become isotropic. Mosesite is therefore dimorphic, the isometric optical condition that agrees with the geometrical form being stable only above 186° , the mineral changing to the dimorphous doubly refracting condition at temperatures below 186° .

As examined at ordinary temperatures, i. e., as the mineral now occurs, the sections show great similarity to kleinite. Much of the material does not extinguish at all, other parts do so four times during a complete revolution of the stage and the interference-colors are fairly brilliant. On crushing a fragment between two glass slides and examining the very minute particles, they are seen to be nearly colorless and, unlike the larger pieces, isotropic. It seems as if the local heat developed by the crushing is sufficient to heat these small particles to at least 186° and cause their reversion to the isotropic state.

Several different fragments were heated on glass slides, in an air oven to the temperature given, with the results shown in the following table :

Effect of heating Mosesite.

Slide with mosesite.	Temp.	Effect.	Probable temp. of change.
First	150°	No change, mineral still doubly refracting.	$150-200^{\circ}$
	200°	Brown and isotropic.	
Second	160°	Brown and doubly refracting.	$180-189^{\circ}$
	167°	Still doubly refracting.	
	180°	" " "	
	189°	Isotropic.	

Third ----	{	169°	Doubly refracting, but section too opaque for further study.	Above 169°
		169°	Doubly refracting.	
		184°	" "	
Fourth ---	{	186°	Nearly isotropic.	
		190°	Isotropic.	186-190°
		184°	Doubly refracting.	
		186°	Nearly isotropic.	
Fifth ----	{	188°	" "	
		190°	Isotropic, except for a few minute doubly refracting spots.	184-186°
		186°	Doubly refracting.	
		192°	Still doubly refracting in places but partly isotropic. This particular piece may have been thicker than the others and therefore did not revert so readily.	186-192° +
Sixth ----	{	186°	Isotropic on thin edges, but doubly refracting in thicker center.	
		192°	Isotropic.	186-192°

From these data the temperature of reversion to the isotropic isometric state probably lies between 180° and 190° and is taken as 186°. If the "molecular inertia" of mosesite is considerable, as is the case with kleinite,* then this temperature, namely 186°, is probably a little high. On cooling, the isotropic mineral does not immediately again become doubly refracting. Examination after 24 hours shows the mineral to be still isotropic. The change back seems to be, like that of kleinite, a very slow one, but doubtless it is gradually taking place. The section of kleinite described † as almost entirely reverted after thirty months is now, after four years, completely changed back again to its original doubly refracting condition.

The optical similarities, shown by these two minerals, coupled with their evident chemical relationship, suggested trying the effect of heating kleinite to the reversion temperature of mosesite (186°). When this was done, kleinite ‡ became optically isotropic like mosesite. The results of the experiments are shown in the table below.

* Hillebrand, W. F., and Schaller, W. T., *The Mercury Minerals from Terlingua, Texas.* Bull. U. S. Geol. Survey, No. 405, 1909, p. 26.

† Loc. cit., p. 25.

‡ Fragments were used that were not parallel to the base as these would become isotropic at 130°, kleinite being uniaxial, hexagonal.

Effect of heating Kleinite.

Slide with kleinite.	Temp.	Effect.
First ----	177°	Doubly refracting, no change.
	187°	“ “ “ “
	194°	“ “ “ “ Probably too thick.
Second ---	177°	Doubly refracting, no change.
	194°	Isotropic.
Third	177°	Doubly refracting, no change.
	194°	Partly isotropic, the remainder doubly re- fracting as before. The isotropic part while still transparent had become brown, the doubly refracting part remaining pale yellow.

It would be premature to speculate on the significance of this observation on the optical behavior of kleinite.

ART. XXI.—*Researches upon the Complexity of Tellurium;*
by WILLIAM R. FLINT.

[Contributions from the Kent Chemical Laboratory of Yale Univ.—ccxiv.]

Introductory.

IN two papers* from this laboratory a description has been given of a hydrolytic method for the fractionation of tellurium. An account also has been given, in the second paper, of results obtained from a preliminary application of the process in which it was indicated not only that the substance might really be complex in spite of the almost conclusively negative evidence hitherto adduced, but also that its anomalous position in the periodic system might be due to the actual presence, as Mendeléeff predicted, of a constituent having a higher atomic weight.

In the work referred to, the fractionation was so conducted as to produce both end fractions simultaneously, and since the method employed was practically that of fractional crystallization, this involved, unless the operation had been long enough continued, the introduction into each of these portions of material from the middle fractions.

It was therefore determined to modify the fractioning process in such a way as to secure a more rapid separation of each end fraction independently, and to apply it to a much larger amount of material.

Preparation of Material.

About one kilogram of crude tellurium dioxide, extracted by hydrochloric acid from electrolytic copper residues, supplied by the Baltimore Copper Smelting and Rolling Co., was treated by the same purification processes as those described in the papers cited, the distillation and redistillation, in hydrogen, being performed in this case in a silica tube, from porcelain boats. The tube was very carefully cleaned between the distillations, and, in redistilling, fresh boats were used.

Plan of the Investigation.

From the method of fractioning adopted, the investigation naturally divides into two parts, in the first of which will be described (1) determinations of the atomic weight of the tellurium in unfractionated material; and (2) the preparation by hydrolysis with water of a series of fractions, together with

* Browning and Flint, this Journal, xxviii, 112 and 347.

atomic weight estimations made upon the tellurium in them. In the second part will be given an account of an experiment upon a fractionation by nitric acid, and of a preliminary investigation of the less easily hydrolyzed fraction.

PART I.

As a check upon the whole work, one hundred and fifty grams of the purified product were dissolved in nitric acid (sp. gr. 1.25) and crystallized out as basic nitrate by evaporation of the solution at about 85° C. After being washed with concentrated nitric acid, the basic nitrate was dried by heating at 110° to 120° C. in specially constructed electric drying ovens through which was passed a current of air dried by sulphuric acid. The air was bubbled first through a solution of potassium hydroxide, then through concentrated sulphuric acid, and finally filtered by passing through a tower containing cotton wool.

Portions of this preparation were then weighed out in platinum and brought to constant weight by heating, for periods of about twelve hours each, at 140° C. in air dried as just stated, in the electric heaters. The temperature was next raised, and the nitric acid expelled from the compound by ignition up to 425° to 450° for twenty to twenty-four hours. The experiments were finally completed by a short ignition over a bunsen burner at such a temperature as would ensure a glassy condition of the fused dioxide.

In all the basic nitrate experiments detailed in this paper, the weighings were made by the method of oscillations, a standardized set of weights employed, and a correction for the inequality of the balance arms applied. Lastly, the weights were reduced to a vacuum. The corrected results of the determinations made upon the unfractionated material, which, excepting number 5, were performed in pairs, are given in Table I. It should be added that in no case was there evidence of the escape of traces of dioxide by volatilization.

TABLE I.
Unfractionated Material.

Exp.	2TeO ₂ .HNO ₃ taken grms.	2TeO ₂ found grms.	Atomic weight of tellurium
1 -----	4.26930	3.56471	127.41
2 -----	3.66863	3.06339	127.48
3 -----	3.17350	2.64983	127.46
4 -----	3.43498	2.86827	127.48
5 -----	5.47269	4.56963	127.44
	20.01910	16.71583	127.45 (Mean)

It may be noted that the mean atomic weight, 127.45, is practically identical with that found by Norris,* and that the concordance of these experiments is quite as good as those given by him. The close agreement of this result with both the figure given by Norris and also those found by numerous other investigators indicates a complete correspondence in quality between the material employed in the present research and that used by others. It also confirms the general conclusion that the atomic weight of tellurium, when prepared by the ordinary methods, is 127.5.

The Fractionation by Water Hydrolysis, and Atomic Weights of the Fractions Obtained.

(See accompanying plan.)

Five hundred grams more of the redistilled tellurium were oxidized by nitric acid and converted to tetrachloride by repeated evaporation with hydrochloric acid. The solution, containing as little excess of acid as possible, was, in four portions, diluted with about four liters each of boiling distilled water and allowed to cool. The white, crystalline dioxide which separated out was collected on a filter and washed. After solution in hydrochloric acid (in slight excess) it was reprecipitated by abundant dilution as before. When the fourth repetition of this process had been made, using in each case only the dioxide which had been previously precipitated by dilution, a small portion of the fourth precipitate was taken out as a sample. This was crystallized from nitric acid by the usual method, and a second series of basic nitrate experiments, conducted in every way like those of Table I, was performed. The data of these are found in Table II.

TABLE II.

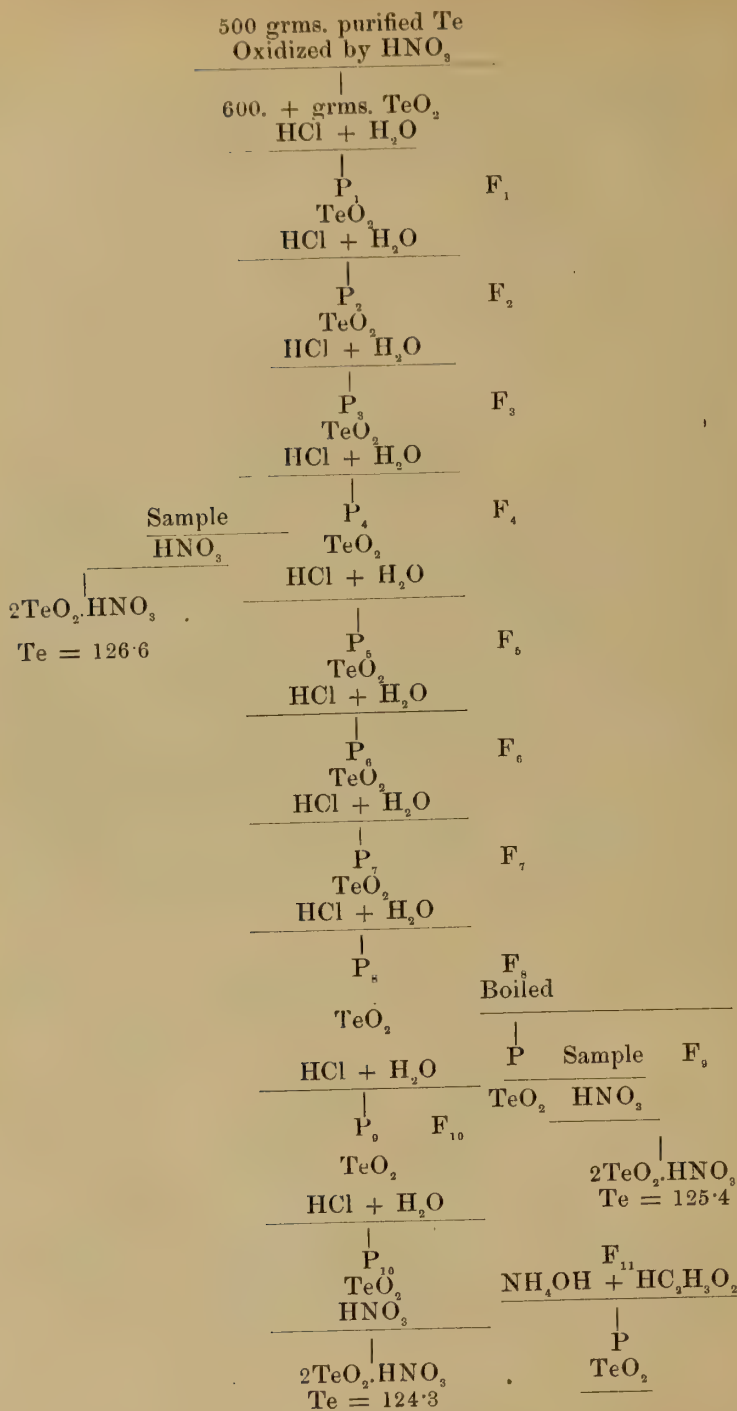
After Four Fractionations.

Exp.	2TeO ₂ .HNO ₃ taken grms.	2TeO ₂ found grms.	Atomic weight of tellurium
1 -----	3.07931	2.56876	126.53
2 -----	2.73622	2.28276	126.62
3 -----	2.36328	1.97153	126.57
4 -----	2.08497	1.73948	126.64
	10.26378	9.56253	126.59 (Mean)

The fractionation process was continued with the remainder of the fourth precipitate in the same manner as before, and the operations repeated without change until ten fractionations

* J. Am. Chem. Soc., xxviii, 1675.

Plan of the First Fractionation.



had been performed. By heating to boiling the filtrate from the eighth precipitate a further separation of dioxide was obtained from this liquid, and boiling for ten or fifteen minutes threw out about 42 grams. Part of this sample was converted to basic nitrate and subjected to the same process of analysis as the previous preparations, the results being recorded in Table III.

TABLE III.
After Eight Fractionations.

(From filtrate.)			
Exp.	2TeO ₂ .HNO ₃ taken grms.	2TeO ₂ found grms.	Atomic weight of tellurium
1 -----	2.12253	1.76842	125.36
2 -----	2.51320	2.09413	125.45
3 -----	3.76225	3.13447	125.32
4 -----	3.88080	3.23336	125.36
	12.27878	10.23038	125.37 (Mean)

Fraction ten consisted of but twenty-three grams of dioxide. Since the fractioning process had reduced the quantity of dioxide from over 600 grams to a little more than twenty, it seemed possible that the limit might have been reached. About fifteen grams were consequently transformed to basic nitrate, in two separate preparations. The purpose of this was to eliminate, if possible, the objection that this lowering of the atomic weight might be due to lack of constancy of composition of the basic nitrate. The first sample, the data of whose analysis by the basic nitrate method (applied exactly as described for the preceding preparations) are given in experiments one and two of Table IV, contained about five grams; the second, experiments three to seven, sixteen grams.

TABLE IV.
After Ten Fractionations.

Exp.	2TeO ₂ .HNO ₃ taken grms.	2TeO ₂ found grms.	Atomic weight of tellurium
1 -----	2.06311	1.71688	124.25
2 -----	2.18903	1.82172	124.27
3 -----	3.56161	2.96446	124.42
4 -----	2.99821	2.49537	124.37
5 -----	2.86977	2.38824	124.27
6 -----	2.47403	2.05898	124.31
7 -----	4.85363	4.03943	124.32
	21.00939	17.48508	124.32 (Mean)

The concordance of these results is sufficiently close to indicate that the two preparations of fraction ten were practically constant in composition. Experiment 7 in the above table was performed in parallel with experiment 5 of Table I.

A comparison of the mean values given in the four preceding tables shows a remarkable lowering of the atomic weight with the progress of the fractionation. In considering the difference between the mean result, 124.3, of Table IV, and that, 125.4, of Table III, it should be noted that, since the material which gave the latter figure was derived from the filtrate of fraction eight, it was to have been expected that its atomic weight would be higher than that of fraction eight itself. Owing to the small quantity remaining of fraction ten, it was impossible to make another direct fractionation. But the dioxide produced in the experiments of Table IV was dissolved in hydrochloric acid and the hydrolysis repeated once more, the precipitate being converted to basic nitrate. The basic nitrate experiments gave 124.62 and 124.64, but these figures cannot be accepted as conclusive. In the first place, they were made upon material which had already been used for previous determinations, in which the dioxide formed had been heated in platinum up to fusion. During the course of the basic nitrate experiments described in this paper, a progressive, but minute, loss of weight was observed in the platinum crucibles used. This fact suggests the possibility that the tellurium may have become contaminated with a little platinum, which would of course raise the atomic weight found in these two experiments. And second, while these two experiments were in progress, an extreme humidity unfortunately characterized the weather. The tendency of this condition would be to increase the atomic weight also, since traces of moisture absorbed by the basic nitrate during those short, but necessary, periods in which it was out of the heaters and desiccator for the purpose of weighing, would tend to produce hydrolysis to dioxide, and the nitric acid liberated from the compound would be expelled in the next heating. This also would increase the value found for the atomic weight. It is therefore at present impossible to conclude with certainty that the figure 124.3 represents the true atomic weight of the element tellurium, since the value may perhaps lie a little below this number.

Conclusion.

Using the customary methods of purification, a large quantity of tellurium has been prepared. By the basic nitrate process, this has been shown, in five experiments with 20 grams of

material, to have the atomic weight 127·5, generally accepted for tellurium. Repeated hydrolysis with hot water of a solution of 500 grams of this preparation in hydrochloric acid has furnished, in ten fractionations, a product consisting of twenty-three grams of dioxide. The tellurium in this fraction, it has been demonstrated, also by the basic nitrate method in seven experiments using twenty-one grams, has an atomic weight of 124·3. Two intermediate fractions, estimated in the same way, give values of 126·6 and 125·4 respectively, these three results taken together exhibiting a progressive diminution of the atomic weight.

In March of the year 1869, Mendeléeff, in announcing the periodic law, made the following statement: * “Die Atomgewichtsgrösse eines Elementes kann bisweilen corrigirt werden, sobald seine Analogien bekannt sind. So muss dass Atomgewicht des Te nicht 128, sondern 123–126 sein.” The problem inferentially stated by him, which for the last forty years has supplied the subject matter of researches too numerous to mention, appears to have been solved, and affirmatively, by the research herein described.

Brauner’s† various low results which he published in 1889; Heberlein’s‡ value of 126·99; Steiner’s,§ of 126·4, obtained in 1901 by fractional distillation of diphenyl telluride; Marckwald’s,|| of 126·85 in 1907, from fractional crystallization of telluric acid; and the figure 126·53, found in 1909 by Browning and Flint,¶ using hydrolysis with water, have been the chief divergences in the past from the accepted value.

The present investigation has furnished more than twenty grams of a purified product possessing an atomic weight of 124·3. Since this preparation was extracted from a large quantity of material which is proved by its atomic weight, 127·45, to correspond to what has been hitherto considered elementary substance, the figure 124·3 is apparently the nearest approach which has yet been made to the true atomic weight of the element tellurium.

PART II.

(Preliminary.)

Experiments upon a Fractionation by Nitric Acid.

In the purification of some crude tellurium by three crystallizations from nitric acid, by the method of Norris, Fay, and Edgerly,** it was observed that a part was rather more insoluble than the rest, in the nitric acid used (sp. gr. 1·25). A sep-

* C. f. Ber., xiii, 1799.

† J. Chem. Soc., iv, 382.

‡ Dissert. Basel, 1898.

** Am. Chem. Jour., xxiii, 105.

§ Ber., xxxiv, 570.

|| Ber., xl, 4730.

¶ Loc. cit.

aration was effected by decantation of the liquid from the less soluble portion. Both fractions were then evaporated to dryness and ignited to dioxide. Carefully weighed equal quantities of these samples were dissolved with equal amounts of hydrochloric acid and diluted with equal amounts of boiling water. After standing for some hours, the precipitates were collected upon Gooch crucibles and washed, dried, and weighed. It was found that the fraction more insoluble in nitric acid gave about 6.5 per cent more dioxide, by the hydrolysis from hot water, than the other, or more soluble, portion. It was proved that this difference was not due to the presence of impurities detectable by careful qualitative analysis.

A similar difference in solubility (in nitric acid) was noted in a recrystallization of part of the basic nitrate prepared from the 150-gram portion of purified tellurium described in Part I of this paper. After the whole of the sample taken had been finally gotten into solution, the greater part was thrown out, as basic nitrate, by sufficient concentration, and the liquid from which it had separated decanted from the crystals. These crystals were washed, and dried in the heater, as usual. The mother liquor was then evaporated to dryness and the residue ignited almost to redness, whereupon it developed an orange-red color and became distinctly crystalline in texture. The color was proved not to be due either to iron or to selenium, by the ordinary tests.

Basic nitrate experiments performed upon the less soluble fraction, exactly as described in Part I, furnished the data (corrected) of the accompanying Table V.

TABLE V.

Exp.	2TeO ₂ .HNO ₃ taken gms.	2TeO ₂ found gms.	Atomic weight of tellurium gms.
1 -----	1.98132	1.65281	126.53
2 -----	1.34204	1.11947	126.48
3 -----	1.36589	1.13945	126.55
4 -----	1.17057	0.97655	126.59
5 -----	1.07610	0.89765	126.50
6 -----	0.98468	0.82145	126.57
7 -----	1.67119	1.39396	126.44
8 -----	1.53443	1.28006	126.56
9 -----	2.53215	2.11231	126.53
10 -----	2.46437	2.05543	126.37
	16.12274	13.44914	126.51 (Mean)

The mean value found in this table, 126.5, is identical with that given by Browning and Flint as referred to in Part I. It

is likewise practically identical with the mean, 126.58, of Table II, in the previous part. Whether this fact indicates that a more rapid fractionation can be secured by the hydrolysis of the nitrate than by that of the chloride, remains for further investigation to prove.

Atomic weight determinations of the more soluble fraction have not as yet been made.

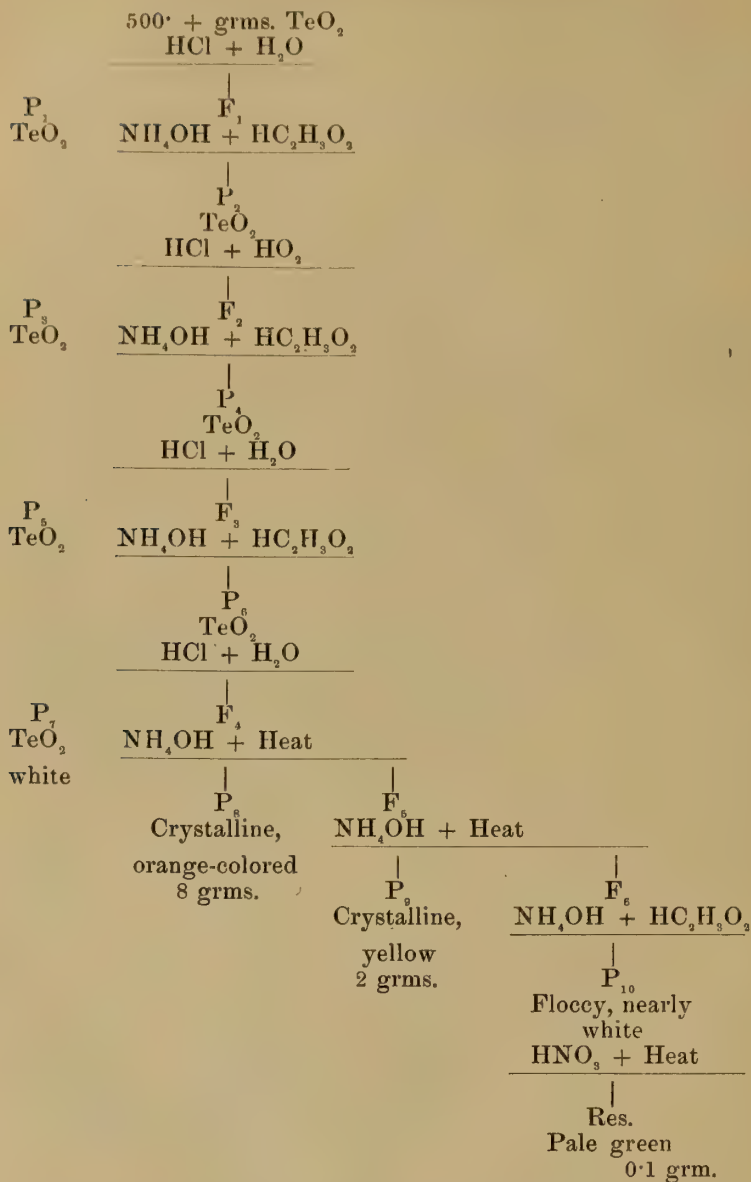
Investigation of the Fraction less easily Hydrolyzed by Water.

(See accompanying plan.)

The tellurium in the filtrates from the water hydrolysis described in the preceding part was recovered by treatment with ammonia and acetic acid. The dioxide thus secured was next dissolved in hydrochloric acid and the solution was diluted abundantly with boiling water and allowed to cool. The filtrate from the dioxide thus precipitated was again heated to boiling, and ammonia and acetic acid were added, in the usual way, to complete precipitation as dioxide of the remaining tellurium. This latter portion was re-treated in the same manner, and the process repeated twice more, each time using only the ammonia-acetic acid precipitate from the preceding operation.

As the result of these four fractionations, almost exactly 500 grams of dioxide were obtained by the water precipitation, while the unhydrolyzed fraction secured by ammonia and acetic acid consisted of scarcely more than ten grams. From the fifth repetition, on the ten gram portion, a very small quantity of crystalline, pure white dioxide was obtained by dilution and cooling of the hydrochloric acid solution. The filtrate was heated to boiling and sufficient ammonia added to neutralize part of the acid, whereupon an orange-colored, crystalline deposit, similar to that obtained in the nitric acid fractionation above described, began to form. Boiling for ten or fifteen minutes threw out about eight grams of this product, which was separated by decantation of the liquid, washed, and dried.

After filtering the liquid and reheating it to boiling, more ammonia was added, but still not enough to neutralize all the acid present. By this means another crystalline deposit was secured, yellow in color, and only a gram or so in quantity. When the filtrate from the last mentioned substance was again heated and finally precipitated completely by ammonia and acetic acid, a minute amount of floccy precipitate appeared. Nothing precipitable by stannous chloride in either acid or alkaline solution was found in the last filtrate, and it was therefore rejected. The floccy precipitate was collected on a filter, washed, and dried. Its amount was too small to admit of its

Plan of the Second Fractionation.

being removed from the paper in any other way, and it was consequently dissolved off by nitric acid (sp. gr. 1.25), the solu-

tion filtered twice on asbestos, and evaporated to dryness. The final product, which was ignited nearly to redness, consisted of about one-tenth of a gram of a pale green powder.

The color of two of these substances suggested possible contamination by iron; that of the third by copper, or perhaps tungsten. No slightest traces of either iron or copper can be discovered by the usual tests. In hydrochloric acid solution all three give, with stannous chloride, black precipitates, similar to tellurium. No bismuth or antimony can be detected. In fact, all reactions so far tried appear to be identical with those given by tellurium, with one exception. When an excess of ammonia is added to a solution of the green substance in hydrochloric acid, the precipitate obtained by neutralization of the acid is not completely dissolved by the excess of the alkali. The liquid filtered from this throws out a black substance, apparently tellurium, when acidified and treated with stannous chloride. The precipitate which did not dissolve in the excess of ammonia, when dissolved, after thorough washing, in hydrochloric acid, gives also a black precipitate with the same reagent. Since tungstic oxide is soluble in ammonia, but is not precipitated (although reduced to lower oxides) by stannous chloride, the presence of tungsten is apparently disproved. It is besides difficult to understand how an element having a fusing point above 3000° C. could be volatilized with the tellurium in the process of distillation at a very much lower temperature than this.

By the use of a greater quantity of material, the investigator proposes to extract sufficient amounts of these products to enable him to determine their nature. This work is already begun, and a report upon it will be made as soon as it can be completed.

ART. XXII.—*The Gravimetric Estimation of Vanadium as Silver Vanadate*; by PHILIP E. BROWNING and HOWARD E. PALMER.

[Contributions from the Kent Chemical Laboratory of Yale Univ.—ccxv.]

SILVER nitrate has long been known as a precipitant of solutions of vanadic acid, but, so far as the authors are aware, no method for the quantitative estimation of vanadium, based on the use of this reagent, has been published. The work to be described was undertaken to determine the conditions under which vanadium could be estimated gravimetrically as silver vanadate.

For this work an exactly neutral solution of ammonium vanadate was used, whose standard had been determined by evaporating accurately measured portions to dryness in a platinum crucible and weighing as V_2O_5 after gentle ignition.

Attempts were first made to precipitate the silver vanadate in acetic acid solution. The solution of ammonium vanadate, acid with acetic acid, was heated to boiling, and a solution of silver nitrate was added, with stirring to coagulate the precipitate. The precipitate, after settling, was filtered off on asbestos, washed thoroughly, and weighed after gentle ignition. The experiments made in this way, under different conditions of acidity, and with different amounts of silver nitrate, are recorded in Table I, and indicate a variation in the composition of the precipitate which is formed in acetic acid solution.

TABLE I.

	V_2O_5 taken gram.	Silver vanadate found gram.	V_2O_5 found gram.	Error gram.
(1)	0.0569	0.1978	0.0871	+0.0302
(2)	0.0569	0.1202	0.0529	—0.0040
(3)	0.1139	0.2275	0.1002	—0.0137
(4)	0.0569	0.2671	0.1176	+0.0607
(5)	0.0569	0.1717	0.0756	+0.0187

The effect was next tried of making the precipitation in exactly neutral solution as follows: The neutral solution of ammonium vanadate, about 200^{cm}³ in volume, was heated to boiling, and a solution of silver nitrate was added in excess, with vigorous stirring to coagulate the precipitate. The precipitate was then filtered off on an asbestos felt contained in a platinum crucible, washed thoroughly, ignited at a gentle heat below the fusing point of silver vanadate, and weighed as $AgVO_3$.

The results, recorded in Series A of Table II, indicate that the composition of the precipitate formed in neutral solution approximates closely to the meta-form.

In the experiments recorded in Series B of Table II, the solution of ammonium vanadate was made ammoniacal with ammonium hydroxide, and this solution was made neutral by boiling until the ammonia was completely expelled. To this solution, diluted to about 200^{cm}³, and heated to boiling, silver nitrate was added, and the procedure given above was followed. The results indicate that the precipitate formed by adding silver nitrate to a solution made neutral by boiling off the ammonia from an ammoniacal solution, is of constant composition.

The experiments of Series C were made to determine whether any solution containing vanadium could be brought into the condition in which the silver metavanadate would be precipitated on the addition of silver nitrate, by making ammoniacal and boiling off the ammonia. To this end the solution of ammonium vanadate was made acid with nitric acid, then made ammoniacal with ammonium hydroxide, and boiled to expel the ammonia; the solution was then treated as in the experiments of Series A. This method, as will be seen, gave the most satisfactory results. In this connection it should be noted that the ammoniacal solution, which is yellow at first, becomes colorless during the boiling, until finally, when the ammonia is almost completely expelled, the solution begins to turn yellow; the boiling should be stopped as soon as the solution begins to turn faintly yellow, because, if the boiling is continued further, the solution becomes too acid, and the precipitate which forms on the addition of silver nitrate has a varying composition which does not correspond to the meta-condition.

The ease with which the silver vanadate settled out on stirring suggested that the vanadium might be estimated volumetrically with a fair degree of accuracy, by adding a standard solution of silver nitrate to the hot neutral solution containing the vanadium, and noting the point at which the precipitation ceased: but attempts to do this met with unsatisfactory results.

The gravimetric estimation of silver by the addition of an excess of a solution of ammonium vanadate to the solution containing the silver was also tried, but was abandoned on account of the unsatisfactory character of the precipitate and the difficulty with which it filtered.

TABLE II.

	V ₂ O ₅ taken gram.	AgVO ₃ found gram.	V ₂ O ₅ found gram.	Error gram.
		(A)		
(1)	0·1139	0·2595	0·1143	+ 0·0004
(2)	0·0569	0·1291	0·0569	+ 0·0000
(3)	0·0569	0·1277	0·0562	+ 0·0007
(4)	0·0569	0·1303	0·0574	+ 0·0005
(5)	0·1066	0·2436	0·1073	+ 0·0007
		(B)		
(1)	0·1066	0·2430	0·1070	+ 0·0004
(2)	0·1066	0·2429	0·1070	+ 0·0004
(3)	0·0533	0·1224	0·0539	+ 0·0006
(4)	0·0533	0·1221	0·0538	+ 0·0005
(5)	0·0569	0·1312	0·0578	+ 0·0009
		(C)		
(1)	0·0569	0·1293	0·0569	— 0·0000
(2)	0·1066	0·2419	0·1065	— 0·0001
(3)	0·1066	0·2424	0·1068	+ 0·0002
(4)	0·1066	0·2422	0·1066	+ 0·0000
(5)	0·0533	0·1215	0·0535	+ 0·0002

ART. XXIII.—*On the Brachiopod genus Syringothyris in the Devonian of Missouri*; by CHARLES SCHUCHERT.

(Contributions from Peabody Museum, Yale University, New Haven, Conn.)

AMERICAN species of *Syringothyris* are said to be restricted to the Lower Carboniferous or, better, the Mississippian, and are known to range from the base of this system into the Spargen formation (Lanesville, Indiana). Professor Greger, of Fulton, Missouri, recently sent the writer specimens of *Cyrtia occidentalis* Swallow (Trans. St. Louis Acad., i, 1860: 648) that are unmistakable individuals of *Syringothyris*. These he gathered from the type locality of the species in the Callaway limestone at Bellamy Springs and elsewhere in Callaway County, Missouri. This limestone is here the basal member of the Devonian invasion, and appears to be either of late Middle or early Upper Devonian time.

The syrinx in *S. occidentalis* is as well developed as in *S. hannibalensis*, in both of which this plate, for pedicle muscle attachment, has not yet developed into the typical form described as the split tube by Hall and Clarke (Pal. N. Y., viii, pt. ii, 1894: 48). In these species the under side of the syrinx is slightly concave, widely open along the inner free end, and is marked by converging muscular growth ridges medially divided by a faint septum. In *S. hannibalensis* the lateral walls of the syrinx close inward and form a more or less well-developed split tube. In other and later species the tube is solid and only the innermost free end has a short depression to which the pedicle muscles are attached.

S. occidentalis is as a rule less transverse than the other species of *Syringothyris*, and in this is most like the earliest Mississippian species. In the later forms *S. carteri* and *S. texta* the valves are more transverse.

Keyes was the first to refer Swallow's species to *Syringothyris* (Missouri Geol. Surv., v, 1894: 86), but as he gave no reasons for this reference and as the writer (Bull. U. S. Geol. Surv., 87, 1897: 199) had not then seen this shell, he preferred to follow Miller's North American Geology and Paleontology, where it is placed doubtfully under *Cyrtina*.

Syringothyris therefore originated in the Cordilleran sea during the later Devonian and not in the Atlantic province as the writer heretofore held, but it was not a conspicuous member of any fauna until Mississippian time. The genus is then present in most of the formations from the early Kinderhook to the Keokuk, and it persists even into the Spargen of the Meramecian series. At no time, however, was there more than one species in a fauna and all these are very much alike.

Another phylum originated in the Atlantic realm of the Appalachian province in *Spirifer randalli*, which also has a well-developed syrinx, but differs from *Syringothyris* of the Mississippian sea in having a strongly plicated fold and sinus. This stock must be separated generically from those of the Mississippian sea because of its different phyletic derivation, and for it is proposed the generic name *Syringopleura* (from *syrinx* and *pleura* or rib, having reference to the plicated fold and sinus), with *S. randalli* Simpson as the genotype. Another species probably also belonging to this stock is *Spirifer alta* Hall. Both occur in the basal Mississippian strata of the Appalachian province and appear to have no later descendants.

Another similar development took place during the Upper Devonian (Ouray limestone) in the southwestern Cordilleran sea in *Syringospira prima* (Kindle, Bull. U. S. Geol. Surv., 391, 1909: 28), a form with an excessively drawn out ventral cardinal area, and valves finely plicate throughout.

Hall and Clarke mention still other stocks of *Spirifer* that tend to develop a syrinx. It would therefore appear that any late Devonian or late Mississippian *Spirifer* with a high cardinal area accompanied by much testaceous deposit in the rostral cavity of the ventral valve between the dental plates, may develop a more or less typical syrinx.

The pedicle in all these forms emerges near the articulating cardinal edge in front of the syrinx and between the slightly diverging deltidial plates. To avoid the lengthening of the inner attached end of the ventral pedicle muscle there was developed the syrinx, a delthyrial plate that was progressively elongated to keep up with the constantly increasing width of the cardinal area. Any independent stock of *Spirifer* that can be shown to develop a syrinx will have to be distinguished under a distinct generic name to bring out its phylogenetic relations. The establishing of such genera, however, cannot be done without the best of material, and the clear evidence that the various stocks of *Spirifer* are actually not directly related phylæ. In this determination the external characters, as the presence or absence of a plicated fold or sinus, lamellose or spinose growth lines, and the nature of the plications will be of much importance.

GEORGE FREDERIC BARKER.

WHEN the writer of the following paragraphs began the study of chemistry in 1872, his text-book was an "Elementary Chemistry," then in its tenth edition, written by Professor George F. Barker. At that time the writer never dreamed that it would be his privilege to become a colleague of this distinguished scientist, nor that later he would be called upon to write in memory of this splendid teacher, profound student, and man of noblest character.

The face of Dr. Barker was familiar to men of science, both in this country and abroad, as he made it a point, whenever possible, to meet with his fellows in science. On such occasions by his affability and courtesy he made a wide circle of friends, who in recent years have keenly felt his absence from their meetings, and were indeed shocked when the message of his death was announced. The writer had the opportunity to meet Dr. Barker daily for many years, not so intimately at first, but later with the greatest freedom and in true companionship. The impression made by him, at all times, was that of an earnest student of science, thoroughly conversant with its most recent advances and able to render subjects, which were dry and unattractive though important, so simple and so fascinating, that the ordinary layman could comprehend them with ease. His lectures to students were celebrated for their clarity of presentation as well as for their wide scope. He was painstaking in the presentation of his subject, and his constant endeavor was to make his students grasp the problems he placed before them. He spared no pains to make abstruse points clear, and if at times he seemed to demand almost too much and be a bit brusque, yet no earnest student was ever turned away; he was, in a word, the true teacher, whose sole object was the welfare of those whom he taught.

In the lecture room he had rare skill and facility as an experimenter, and one of his chief joys was to illustrate his lectures, as far as possible, with an abundance of attractive and striking experiments. He often presented the most intricate topics before large audiences, reaching sometimes into the thousands, and so uniformly brilliant was his success that he became noted throughout the country as one capable of popularizing science as few could do it. The writer recalls an occasion in his younger days, when the Academy of Music in Philadelphia was filled to its dome with an intensely interested and intelligent audience assembled to listen to his lecture on "Sound," and, while seated in the "sky parlor" of the immense auditorium, enjoying the discomforts peculiar to his position, so

intensely absorbing was the lecture and its experiments that at its conclusion it was difficult for him to realize that he had actually sat there more than an hour.

Dr. Barker was much esteemed in the community where he lived by persons of all ranks. For a number of years he served on the Board of Education in the city of Philadelphia, and there exerted an influence which was entirely for the good, and never to be forgotten. His contributions to municipal interests included studies of the local water supply, of the quality of illuminating gas, and of the means for protecting public buildings from lightning. At various times he appeared as an expert in scientific matters, and in this field further demonstrated his spirit of careful investigation and absolute integrity and loyalty, as well as ability to be just and fair to all. Many of the cases called for the highest scientific knowledge and accuracy, which were abundantly supplied by him.

By his colleagues on the teaching staff of the University of Pennsylvania he was most highly valued. His services were constantly engaged upon committees, and those who worked with him in such duties entertained but one impression, to wit, that he was capable of handling the most intricate and perplexing problems with fairness, calmness, and the best judgment. Indeed, it was a pleasure to be associated with him in work of this description; his hearty coöperation and his many helpful suggestions in the solution of university problems were appreciated by all his colleagues.

Dr. Barker's early academic training was received in the Boston Public Schools, and at the academy in South Berwick, Maine. He further served an apprenticeship with Joseph Weightman, a maker of scientific instruments, going thence to the Sheffield Scientific School of Yale University, where he received the degree of Bachelor of Philosophy in the year 1858. He was deeply attached to his Alma Mater, and invariably spoke in terms of the highest praise and affection of his early teachers. His serious student days had, however, a bit of the modern in them, for if the writer remembers correctly, he was a member of the Varsity crew in the year of his graduation. Some years later, in the autumn of 1869, he became professor of Physiological Chemistry and Toxicology in the Yale Medical School, a chair created for him. During this period he served as expert for the State in several poison cases, the most noted being the Lydia Sherman case in New Haven.

His active scientific career may be said to have commenced about this time. Thus this Journal in 1867 ((2), xliii, 252) contains a brief article "Upon the Silvering of Glass," which is a modification of a suggestion of Böttger, consisting in adding to a boiling solution of Rochelle salt a solution of argentic nitrate,

after which the boiling was continued for eight or ten minutes, the liquid allowed to cool, and then filtered. A second portion of the original silver solution was treated with ammonium hydroxide until the precipitate formed was almost redissolved, after which water was added and the liquid filtered. To silver glass, equal portions of these two fluids, thoroughly mixed, were poured upon it. After a lapse of about ten minutes, a brilliant layer of metallic silver was deposited. By repeating the process the layer could be thickened to any desired extent. A somewhat earlier article is entitled "Account of the Casting of a Gigantic (Rodman) Gun at Fort Pitt Foundry" (*ibid.*, xxxvii, 296); this contains some important practical suggestions.

An interesting contribution is made by Dr. Barker, in the same Journal (2), xliv, 263, 1867), in support of the view that formic acid is carbonous acid. He believed this to be true because of the ready formation of formic acid by the partial oxidation of carbon, and also because it resulted from the oxidation of carbonic acid. For these reasons he further concluded that formic acid was the acid of bivalent carbon.

In an extended communication "On Normal and Derived Acids," (*ibid.*, xliv, 384), he arrived at the following conclusions:

"1. That all the bonds of any simple radical may be saturated by the monad hydryl (OH). 2. That the compounds thus formed, being evidently normal, are conveniently designated by the prefix *ortho*. 3. That the equivalence of negative radicals varies through several stages, while that of positive rarely changes, and hence, that there may be a series of ortho-acids from a given negative radical, but only a single base from a positive one. 4. That by the removal of the elements of water from a normal or ortho-acid, a derived acid is produced, which may be indicated by the prefix *meta*. 5. That when there are several such derivatives, the Greek numeral prefixes di, tri, tetra, etc., may be used to indicate the number of molecules of water removed from the ortho-acid to yield the meta-form. 6. That intermediate between the simple ortho- and the meta-acids are others containing more than a single atom of the negative radical; and that these acids may be designated by di, tri, tetra, etc. (according to the number of negative atoms) prefixed to the name of the acid, while the number of molecules of water removed from a multiple of the normal acid to form them is indicated by the same numerals prefixed to the meta. 7. That while the negative atoms in the compounds just mentioned are united by oxygen, there may be other compounds whose negative or positive atoms are united directly; thus producing a fourth class of acids and of bases.

"By classifying thus the substances known as acids and bases, —and, of course, the salts derived from them—it is hoped that their relations to each other may be made clearer. And by giving them systematic names, their position in the series may be fixed, and a step taken toward the establishment of a national nomenclature."

In 1870, appeared his text-book of "Elementary Chemistry, Theoretical and Inorganic," which ran through many editions as well as translations into other languages. This was the first book in our language in which modern chemistry was presented systematically. The style of the book, as so many can testify from its study, is concise and clear. Wolcott Gibbs spoke of it as "a book wholly in the spirit of the most advanced thought in the science."

During his life at New Haven, he contributed a note "On the spectrum of an Aurora which appeared at New Haven, November 9, 1871." The point of particular interest in this observation was the fact that the line of wave-length, 502, was not laid down in any authority accessible to the observer, as having been noted in the spectrum of the aurora. He adds: "Indeed, no previous observer, so far as I know, has seen any auroral line between the Fraunhofer lines *b* and *F*" (this *Journal* (3), ii, 465, 1871). Sometime later, he presented a second contribution "On the Spectrum of an Aurora of October 24, 1872." This aurora, like that of 1871, was distinguished by its radiant crimson color, and by its form. Dr. Barker remarks that in the lines that appeared in the spectrum, none was new, though no previous observer had seen all of them at once. Vogel had seen five and four had been seen by Dr. Barker. Two of the lines nearly coincided with the solar lines *F* and *G*, but a considerable difference was observed in the spectrum of this aurora and that of 1871, for three lines of the aurora of 1872 had no corresponding line in the spectrum of the aurora of 1871.

Dr. Barker was assistant to Dr. Bacon in the Harvard Medical School from 1859 to 1861; Professor of Chemistry in Wheaton College, Illinois, 1861; then in the Albany Medical College, where he received the degree of Doctor of Medicine (1862–1863), making while there a chemical examination of the viscera of a dead body, the first time it had ever been done in this country; next, in the University of Pittsburg (1863); he also delivered the lectures on Chemistry at Williams College in the years 1868 and 1869; and, after service in his Alma Mater, to which reference has already been made, he became Professor of Physics in the University of Pennsylvania (1872), where the remainder of his life was spent. At this period he published a contribution of considerable length, with the aid

of illustrations, on "A New Vertical Lantern Galvanometer," in which claim is made for the general principles of construction of the instrument, and the advantages possessed by it in the readiness with which it could be put into use, the brilliancy of the illuminated circle of light which it gave upon the screen, its great range of delicacy by which all experimental requirements might be answered, and, finally, the satisfactory character of its performance as a demonstration galvanometer (Proc. Amer. Phil. Soc., xiv, 440). This was followed by a communication "On the Measurement of Electromotive Force (ibid., xx, 649), in which the author states: "Having had occasion to make measurements of electromotive force by the method of comparison, I have been led to devise a form of standard cell, which appears to have advantages over others heretofore used as to justify me in bringing it before the Society."

In 1880, before the American Association for the Advancement of Science, at its Boston meeting, Dr. Barker, as retiring President, delivered an address upon "Some Modern Aspects of the Life-Question," from which the following paragraphs are introduced:

"As Preston has suggested, if we regard this ether as a gas, defined by the kinetic theory that its molecules move in straight lines, but with an enormous length of free path, it is obvious that this ether may be clearly conceived of as the source of all the motions of ordinary matter. It is an enormous storehouse of energy, which is continually passing to and from ordinary matter, precisely as we know it to do in the case of radiant transmission. When potential energy becomes kinetic, the ether loses and the matter gains motion. When kinetic energy becomes potential, the lost energy of the matter is the motion gained by the ether. Before so simple a conception as this, both potential energy and action at a distance are easily given up. All energy is kinetic energy, the energy of motion. Giving now to the ether its storehouse of tremendous power, and giving to it the ability to transfer this power to ordinary matter upon opportunity, and we have an environment compared with which the strongest steel is but the breath of the summer air. In presence of such an energy it is that we live and move. In the midst of such tremendous power do we act. Is it a wonder that out of such a reservoir the power by which we live should irresistibly rush into the organism and develop the transmitted energy which we recognize in the phenomema of life? Truly, as Spinoza has put it, 'Those who fondly think they act with free will, dream with their eyes open.'"

"Such are now the facts and theories to be found in the science of to-day considering the phenomena of life. Physiologically considered, life has no mysterious passages, no sacred precincts into which the unhallowed foot of science may not enter. Research has steadily diminished day by day the phenomena sup-

posed vital. Physiology is daily assuming more and more the character of an applied science. Every action performed by the living body is sooner or later, apparently, to be pronounced chemical or physical. And when the last vestige of the vital principle as an independent entity shall disappear from the terminology of science, the word "Life," if it remain at all, will remain only to signify, as a collective term, the sum of the phenomena exhibited by an active organized or organic being."

In following the career of our friend there is plainly seen a versatility on his part, as well as a keen interest for other branches of science than that one to which he gave the best years of his life. Thus, he is found a member of an expedition to Rawlins, Wyoming, for the purpose of reporting "On the Total Solar Eclipse of July 29, 1878"; his particular duty being to observe with an analyzing spectroscope the presence, either of light, or of dark (Fraunhofer), lines in the spectrum of the corona. (See Proc. Amer. Phil. Soc., xviii, 1880.) Again, in connection with Professor Rowland, he reported "On the Efficiency of Edison's Electric Light." See this Journal (3), xix, 337.

Dr. Barker was the first person to exhibit radium in this country (1894) after its isolation by Madame Curie in Paris. Radio-activity appealed so strongly to him, that it is not surprising to find a paper of his on "Radio-activity of Thorium Minerals" in this Journal (4), xvi, 161, 1903). In this communication, the author introduces a number of original contributions. He repeated the experiments of Hofmann and Zerbán, relative to the radio-activity of Brazilian monazite, which contains no uranium, and confirmed the results of these observers, to wit: that the thorium from this monazite is probably radio-active. From a series of experiments, he further concluded that thorium is a primary radio-active substance, and added that the thorium emanation rapidly decays, falling to one-half its value in one minute, while that of the radium emanation retains its active properties for several weeks. On the other hand, the excited radio-activity produced by the former emanation is much more prominent than that produced by the latter. Since excited radio-activity can be produced on bodies if the emanation be present, even in the absence of a radio-active substance, and since the amount of effect is directly proportional to the amount of emanation, it follows, first, that the production of excited radio-activity is a property of the emanation, and, therefore, is also produced in bodies where the radio-active emanations from thorium and radium are present: and second, that uranium and polonium, which do not give forth any emanation, do not possess the power of exciting radio-activity. In the present view of

science, therefore, it would not be probable that the radio-activity of thorium is a secondary or excited radio-activity due to the uranium associated with it in the minerals previously named."

A very instructive address upon "Radio-activity in Chemistry" was delivered by Dr. Barker before the Chemical Society of Columbia University; it appeared in full in the *School of Mines Quarterly* (xxiv, 267). It has historical value, and will prove helpful to all wishing to familiarize themselves with the subject. It is accompanied with bibliographies covering 90 titles by the most prominent investigators in this particular field of research. In 1899, Harper and Bros. issued a small volume of 75 octavo pages on "Röntgen Rays," in which are incorporated memoirs by Röntgen, Stokes, and J. J. Thomson, translated and edited by Dr. Barker.

On the 27th of May, 1893, the American Philosophical Society celebrated the 150th anniversary of its foundation, on which occasion Dr. Barker offered a paper on "Electrical Progress since 1743." This paper is a review of the advances in Physics since that early date, emphasizing in particular the contributions to electrical science by such persons as the immortal founder of the Society, Benjamin Franklin, and by Kinnersley, Robert Hare, Joseph Henry, Joseph Saxton, David Rittenhouse, and Alexander D. Bache. "The labors of these men have mightily contributed to advance the development of scientific thought throughout the world, and so to bring about that exceptional evolution of electrical facts and theories which is the distinguishing feature of the science of the nineteenth century." This little brochure is indeed worthy of study by every student of the physical sciences.

Still other communications of Dr. Barker are "On the Henry Draper Memorial Photographs of Stellar Spectra" (*Amer. Phil. Soc.* xxiv, p. 166), "On the Use of Carbon Bisulphide in Prisms," (*this Journal* (3), xxix, 269), in which communication there is presented to the public the observations of his friend, Dr. Henry Draper, taken from the notes of the latter after his death; and "The Microphone of Hughes" (*ibid.* (3), xvi, 60), in which Dr. Barker takes occasion to say that the results obtained by Hughes had been clearly anticipated by more than a year by those of Edison.

Biographical memoirs of Frederick Augustus Genth, of Henry Draper, of John William Draper, and of M. Carey Lea were written for the National Academy by Dr. Barker, and he also prepared for the Smithsonian Institution annual reports upon Physics from the year 1881 to 1885, inclusive. These amount to 253 pages and represent the most recent advances in the science during these years.

From 1868 to 1900 he was associate Editor of this Journal, and the abstracts of chemical and physical papers which he contributed regularly during this period are remarkable for their clearness and accuracy. In 1874-75 he was Editor of the Journal of the Franklin Institute.

In 1892 appeared his "Physics, Advanced Course" from the press of Henry Holt & Company, which immediately met with a most hearty reception and became a standard among the text-books on this important subject.

It follows naturally that to one so active in the scientific world there should have been awarded numerous honors. Thus, in 1881, Dr. Barker was United States Commissioner to the Paris Electrical Exhibit, a delegate to the Electrical Congress, and Vice-President of the Jury of Awards, receiving the decoration of Commander of the Legion of Honor in France; in 1884, he was United States Commissioner to the Electrical Exhibit in Philadelphia; and in 1893, a member of the Jury of Awards of the World's Columbian Exposition. He was an active member of the National Academy of Sciences, serving on many of its important committees, and also of the American Association for the Advancement of Science, of which he was Vice-President twice, delivering on one of these occasions an address on "The Molecule and the Atom," a most valuable contribution to theoretical chemistry, and President in 1879; his presidential address in 1880 has already been referred to. He was a corresponding member of the British Association. He was President of the American Chemical Society (1891), the subject of his presidential address being "The Borderland between Physics and Chemistry." He was Secretary and later a Vice-President of the American Philosophical Society from 1899 until 1909. He was a member of the Physical Society and of the Deutsche Chemische Gesellschaft. In 1899 he became an honorary member of the Royal Institute of Great Britain. He was the recipient of the following academic honors: Doctor of Science from the University of Pennsylvania in 1898; LL.D from Allegheny College in 1898; and LL.D from McGill University in 1900.

He became Emeritus Professor of Physics in the University of Pennsylvania in 1900. He was a member of the Century Club of New York and the University Club of Washington.

In 1861, Dr. Barker was married to Mary M. Treadway of New Haven, Conn., who with three daughters survive this devoted and loving husband and father.

Dr. Barker was born at Charlestown, Mass., July 14, 1835, and died at Philadelphia on May 24, 1910. His was a beautiful life, so full of service to his fellow-men and so rich in its achievements that it will ever remain a most precious memory to his many friends.

EDGAR F. SMITH.

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

ART. XXIV.—*On the Nature of the Ionization Produced by a Rays* ;* by FRANK E. WHEELLOCK.

[Contributions from the Sloane Physical Laboratory of Yale University.]

WHEN a gas is ionized by α rays, it is well known that saturation is obtained only when a large potential gradient is applied between the plates of the ionization chamber. This is much larger than would be necessary if the lack of saturation were due to general recombination of the positive and negative ions formed, if they are distributed throughout the volume of the gas.

Bragg and Kleeman† have explained the lack of saturation experimentally obtained, on the hypothesis of “Initial Recombination”; the two ions made by corpuscular dissociation of a molecule, situated initially in the immediate vicinity of each other, are able to recombine and thus escape the electrode placed to receive them. On this hypothesis, lack of saturation would depend upon the number of ions formed per c.c. in a unit of time; it would be independent of the size and shape of the ionization chamber; saturation would be easier with diminished pressure, and “Initial Recombination” would be greater in the more complex gases.

The experiments of Bragg and Kleeman show the above facts and “Initial Recombination” seem to be a reasonable explanation of the lack of saturation at low voltages.

Kleeman‡ has shown that “Initial Recombination” is practically absent in air ionized by X rays and is very small in gases

* A Thesis presented for the degree of Doctor of Philosophy at Yale University, June, 1910.

† On the Recombination of Ions in Air and other Gases, *Phil. Mag.*, xi, 1906.

‡ Recombination of Ions, made by α , β , and γ rays, *Phil. Mag.*, xii, p. 273, 1906.

ionized by β and γ rays. These ionizing agents seem to effect a complete separation of the negative ions from their parent molecules. He has shown that lack of saturation for weak ionization with α rays is not due to diffusion of ions, nor does it depend upon α , the coefficient of recombination. "Initial Recombination" is greater the slower the velocity of the ionizing α particle, which probably means, the slower the velocity of the α particle the less the velocity of the ejected electron.

Moulin* has interpreted the lack of saturation on the hypothesis suggested, by Langevin, that in the case of ionization by α rays, where the number of ions produced by each α particle is very great, the ions produced are not at all uniformly distributed in the volume of the gas, but are distributed, at least initially, in columns along the trajectory of the α particle.

The ordinary recombination obtained between ions of the same column ought to exceed many times that which would be obtained for the same number of ions distributed throughout the volume. According to this hypothesis, recombination should be greater when the field is applied along the path of the α particle than when it is at right angles to the path. The parallel field would not break up the columns, while the perpendicular field would produce a separation of the positive and negative ions, by breaking each column up into two.

Moulin obtained saturation at about 200 volts per cm. when the field was applied at right angles to the path, while from 1200 to 1500 volts per cm. were necessary for the parallel field. He also found that saturation was more easily obtained when the pressure was decreased.

In a second paper† Moulin describes some experiments using CO_2 and H_2 instead of air, and obtained results which confirm those of his previous paper. He also applied a field inclined at an angle of 45° to the path of the α particle and obtained curves which were in good agreement with those obtained by calculation.

Moulin therefore concludes that the "Initial Recombination" effect is negligible in comparison with that of general recombination (αn^2) within the columns.

For volume ionization, general recombination depends upon N , the number of ions per c.c. If the ions are formed in columns, the density of ionization within the columns would be very great, since the ions would occupy only a very small fraction of the total volume of the chamber.

It would be expected, therefore, on this hypothesis, that recombination would be different at different parts of the range of the α particle, being greatest where the maximum number of ions is produced by the α particle.

* Ionization of Gas by α rays and Hypothesis of Initial Recombination, *Le Radium*, May, 1908.

† *Comptes Rendus*, June, 1909.

On the hypothesis of "Initial Recombination" it would be expected that recombination would be less in the part of the range where the velocity of the α particle is greater, since the electron would probably be ejected with greater velocity and thus have more chance to escape the remaining positive ion.

The α particle is a more efficient ionizing agent near the end of its path, but since it is moving slower here than when the source is nearer the chamber, more recombination would take place. This would also be the case if the lack of saturation were due to columnar ionization, because of the greater density of ions within the columns.

The purpose of the experiments here described is:—

I. (a) To compare the saturation curve obtained when an electric field is applied parallel to the path of the α particle with that obtained when the field is perpendicular to the path; (b) To compare the α ray curves with those obtained when β and γ rays are used as ionizing agents.

II. To test for the existence of columnar ionization.

III. To get a mathematical expression for the saturation curve, on the hypothesis of ionization in columns, and to compare the calculated curves with those experimentally obtained when the field is applied parallel to the path of the α particle.

IV. To show that the lack of agreement between the calculated and experimental curves is not due to an inclination of the columns in the ionization chamber used.

V. To compare the curves obtained with the source at different distances from the ionization chamber, for both parallel and perpendicular fields.

VI. To compare the curves obtained at different pressures in both chambers.

Description of Apparatus.

For the field parallel to the path of the α particle, the apparatus used (fig. 1) was similar to that of Bragg and Kleeman.

The ionization chamber, 7.5^{cm} in diameter and 4^{mm} in depth, was formed of a wire gauze N, insulated from the supporting ring by small pieces of amber, and a brass plate A, insulated from the top, E, of the containing vessel by means of an ebonite plug. A second wire gauze, D, grounded through the top of the containing vessel, formed with N a second ionization chamber, which prevented stray ions from entering the ionization chamber proper.

The plate A was connected to one pair of quadrants of a Dolezalek electrometer, the second pair of quadrants being earthed. The gauze N was connected with a battery and could be charged to any desired potential. The high potential wire C was carefully screened to prevent stray ions from being

carried over to the plate A. The polonium, or other radioactive substance used, was placed on a carrier, R, which could be moved up and down by means of the screw G, the position of which was given by the scale S.

The apparatus used for testing the effect of a field perpendicular to the path of the α particle (fig. 2) consisted of a brass

FIG. 1.

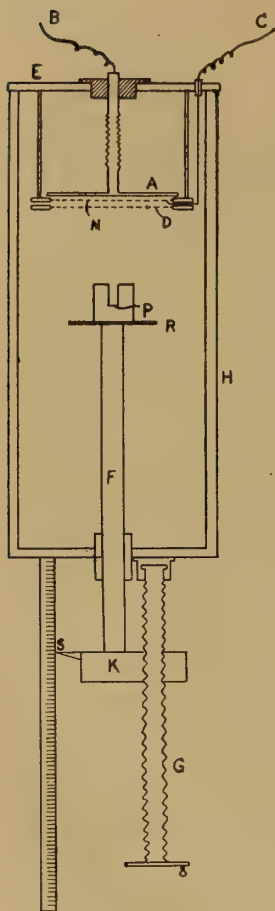
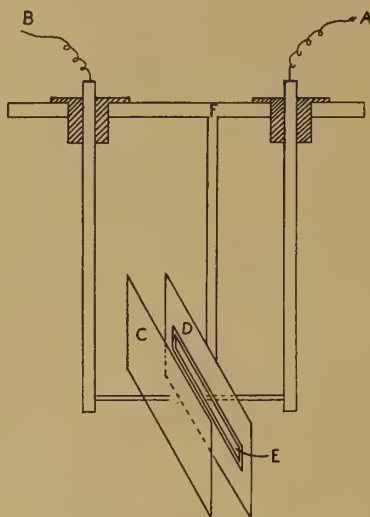


FIG. 2.



plate, C (8.5 cm by 2.5 cm), connected by B to a battery, a narrow brass strip, E (7.2 cm by 0.4 cm), connected to one pair of quadrants of the electrometer, and a brass plate, D, surrounding E and separated from it by an air space of 0.5 mm . The plate D was grounded through the top of the containing vessel and served as a guard ring.

This chamber was used in the same containing vessel as that shown in fig. 1, so that the radio-active material being below, the field was perpendicular to the trajectory of the α particle.

I. (a) *Comparison of Curves obtained with the Field parallel and perpendicular to the Path of the α particle.*

When a gas is ionized by α rays, if the ions are formed in columns along the path of the α particle the saturation value of the current would be obtained for a much smaller potential gradient applied between the plates, when the field is perpendicular, than when it is applied along the path of the α particle.

The following data show this to be true and agree with the results obtained by Moulin:

<i>Parallel Field.</i>			<i>Perpendicular Field.</i>		
Source 2.6 ^{cm} from the middle of the chamber.			Source 2.6 ^{cm} from the middle of the chamber.		
Volts/cm.	Current	% lack sat.	Volts/cm.	Current	% lack sat.
5	12.77	33.9	2	11.98	59.0
10	13.67	29.3 (1)	4	15.95	45.4
20	15.1	21.8 (2)	10	20.76	29.3 (1)
40	15.95	17.4 (3)	20	23.80	18.5 (2)
100	17.45	9.7	40	26.40	9.6 (3)
200	18.35	5.0 (4)	80	27.85	4.6
400	19.15	1.9	120	28.65	1.9
800	19.32	0.0	200	29.08	0.4 (4)
			400	29.18	0.07
			1000	29.20	0.00

NOTE.—For a direct comparison, see (1), (2), (3), (4), above, or fig. 3.

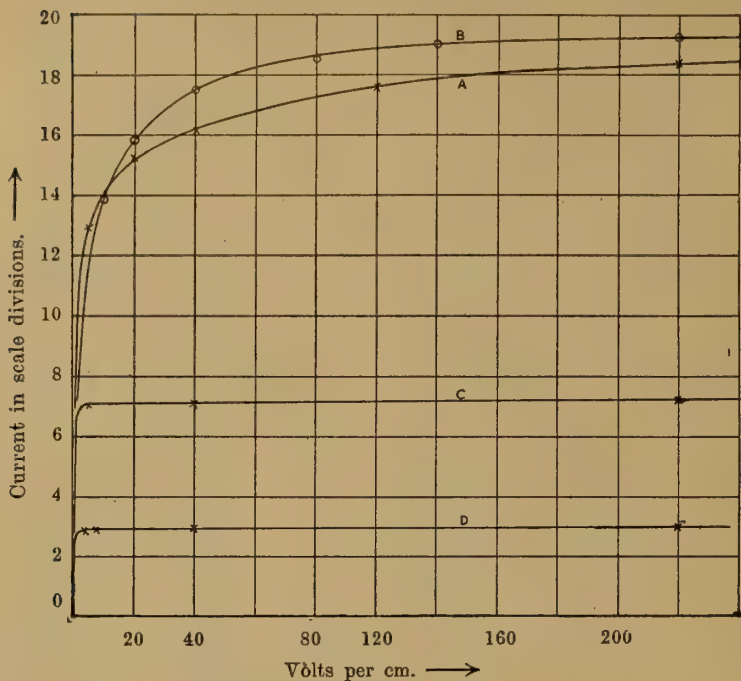
The saturation curves are practically the same when a positive charge is applied to the gauze of the ionization chamber as they are for a negative charge. This is true when the field is applied parallel or perpendicular to the path of the α particle.

(b) When a weak source of β and γ rays is used as the ionizing agent, saturation is practically obtained for a very small potential gradient applied between the plates.

<i>Parallel Field.</i>			<i>Perpendicular Field.</i>		
Source 5.1 ^{cm} from the middle of the chamber.			Source 2.7 ^{cm} from the middle of the chamber.		
Volts/cm.	Current	% lack sat.	Volts/cm.	Current	% lack sat.
5.0	6.95	6.0	2.0	2.75	5.2
40.0	7.0	5.4	4.0	2.84	2.1
200.0	7.2	2.7	8.0	2.87	1.0
800.0	7.4	0.0	40.0	2.9	0.0
1200.0	7.4	0.0	200.0	2.9	0.0
			1000.0	2.9	0.0

NOTE.—For curves see fig. 3.

FIG. 3.



A = α ray curve, parallel field.

B = α ray curve, perpendicular field.

C = β and γ ray curve, parallel field.

D = β and γ ray curve, perpendicular field.

The fact that for β and γ rays, saturation is obtained for small potential differences between the plates, has been explained by Kleeman as due to the electron, emitted in the act of ionization, being shot off with a velocity great enough to effect complete separation from the remaining positive ion, and therefore initial recombination would be negligible.

General recombination would have very little effect in this case, since it is volume ionization from a very weak source.

II. Evidence of Columnar Ionization.

When a gas is ionized by β or γ rays, it has been seen that saturation is obtained at small voltages, if the ionization is small. It is found by experiment that as the ionization increases, a stronger field is necessary to obtain the saturation value.

In the case of ionization by β rays, the ions are distributed throughout the volume of the gas, and general recombination, which depends upon the number of ions per c.c. in the gas, would be greater as the ionization is increased. It would not be expected that the ratio of the currents obtained with two sources of different intensities would be the same for different potential gradients. This is in accord with the ordinary theory of volume ionization and with all experiments hitherto made on ionization produced by β , γ , and Röntgen rays.

On the other hand, when a gas is ionized by α rays, if the ions are formed in columns along the path of the α particle, an electric field applied along the path, that is along the axis of the column so formed, would not break up the column and the recombination occurring would be between ions belonging to the same column. It would be expected that the ratio of the currents obtained with sources of different intensities would be constant for different potential gradients applied, since each α particle makes the same number of ions in its path, and the density of ionization would be the same in any one column.

When the field is applied at right angles to the direction of the column, each column would be separated into two, one of positive and the other of negative ions.

With the perpendicular field two cases present themselves: first when the source is so weak that there are very few α particles given off; second, when a stronger source is used.

In the first case, very few columns would exist in the ionization chamber during the time required for the ions present to be carried over to the receiving plate by the electric field. The ions of one column would have little chance to recombine with those of another in going across the chamber.

In the second case, with the stronger source, enough columns might exist in the chamber at any one time, so that the ions of one column would, when the field is applied, come within the sphere of influence of those of the opposite sign from another column. Recombination might then take place not only between ions of the same column but between those of different columns.

In this case the ratio of the currents obtained with a given field would not be constant, because of the added recombination of ions of different columns, which would vary with the number of columns present in the chamber.

To apply this test for the existence of ions in columns it is necessary to obtain curves from sources of different intensity, with both parallel and perpendicular fields.

(a) Curves were obtained with the radio-active source bare and when covered with a wire gauze to cut out part of the α particles. The density of ionization would be the same wherever ions exist, i. e., within the columns.

Parallel Field. Source 2.6^{cm} from the middle of the chamber.

Volts / cm.	Current		Ratio of Currents
	Without gauze	With gauze	
5	7.7	3.13	2.46
10	8.35	3.35	2.5
20	9.12	3.59	2.54
40	9.65	3.76	2.57
100	10.6	4.2	2.52
200	11.2	4.51	2.48
400	11.5	4.7	2.45

*Perpendicular Field.*Source 2.6^{cm} from the middle of the chamber.

Volts / cm.	Current		Ratio of Currents
	Without gauze	With gauze	
2.1	9.88	5.25	1.88
4.2	13.25	6.5	2.04
10.6	17.33	7.82	2.22
21.0	20.0	8.85	2.26
43.0	22.2	9.62	2.31
85.5	23.6	9.95	2.37
126.0	23.8	10.05	2.38
168.5	24.0	10.12	2.38
211.5	24.1	10.14	2.38

The ratio of currents is approximately constant for the parallel field but increases with the potential gradient for the perpendicular field; this is as would be expected if the ions are initially formed in columns. For the perpendicular field the ions of one column might interfere with those of another.

(b) Two specimens of polonium were then used, one of which was about twenty-nine times as strong as the other, and the following data were obtained:

Parallel Field. Source 2.6^{cm} from the middle of the chamber.

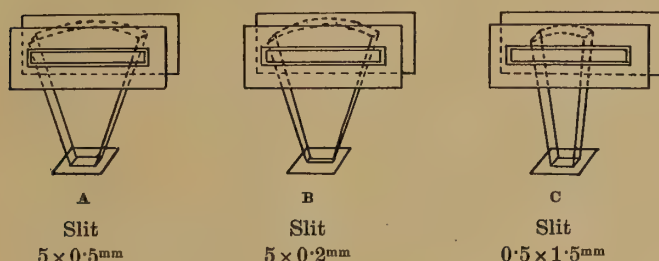
Volts / cm.	Current		Ratio of Currents	Ratio for 3 min. readings without cap.
	Weak	Strong		
	Polonium	Polonium		
	3 min. readings	1 min. readings cap.		
		196.46 added		
5.25	1.39	6.82	4.9	29.4
20.9	1.63	8.0	4.9	29.4
42.5	1.75	8.55	4.89	29.34
86.3	1.91	9.42	4.93	29.58
196.3	2.08	9.85	4.73	28.4
355.0	2.15	10.1	4.7	28.2

Again the ratio of deflections is approximately constant.* This could not be so if volume ionization existed, since the density of ionization in the one case would be twenty-nine times the density in the other, and general recombination would have a very different effect in the two cases.

(c) Experiments were then made with the field at right angles to the path of the α particle, in which fan-shaped beams of different sizes and shapes were used. These were obtained by placing slits of different dimensions over the source.

The different beams used were as shown in fig. 4.

FIG. 4.



Perpendicular Field.

Source 2.6 cm. from the middle of the chamber.

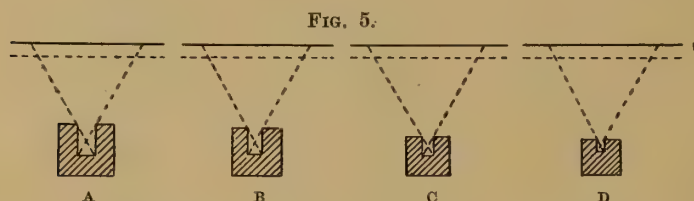
Volts / cm.	Current			Ratio of Currents		
	A	B	C	A/B	A/C	C/B
	Slit $5 \times 0.5 \text{ mm}$	Slit $5 \times 0.2 \text{ mm}$	Slit $0.5 \times 1.5 \text{ mm}$			
2.1	9.88	2.57	3.7	3.84	2.67	1.44
10.6	17.33	3.35	5.36	5.17	3.23	1.6
21.0	20.0	3.65	5.77	5.48	3.47	1.58
43.0	22.2	3.9	6.29	5.7	3.53	1.61
85.5	23.6	4.07	6.56	5.8	3.58	1.61
211.5	24.1	4.15	6.68	5.8	3.6	1.61

From the above data it will be seen that the ratio of the currents C/B is practically constant. The ionization in both of these cases is small and the result appears to indicate that there are not enough columns in the chamber at any time to get interference of the ions of one column with those of another.

* It is interesting to observe, that to compare the ionization produced by α rays from different sources, it is not necessary to obtain the saturation value of the current. This is very convenient, since for ionization by α rays saturation is obtained only when the potential difference between the plates is very large, when the field is applied parallel to the path of the α particle.

The current obtained with the beam A is much larger than that with either B or C. The ratios A/B and A/C are not constant. This looks as if, with beam A, enough columns do exist to give interference of the ions between columns and consequently more recombination occurs.

(d) A further test for columnar ionization was made as follows: the radio-active source was covered by hollow cylinders of different diameters and heights. The source was kept at a fixed distance (2.6^{cm}) from the chamber and the internal dimensions of the hollow cylinders were varied so that the area of the plate receiving ions was constant in all cases, as shown in fig. 5.



The internal dimensions of the cylinders are given below.

	Diameter	Height
A	5 mm	7.5 mm
B	4	6.0
C	3	4.5
D	2	3.0

The following data were obtained:

Parallel Field.

Source 2.6^{cm} from the middle of the chamber.

Volts/cm	Current		Ratio of Currents
	Cylinder $5 \times 7.5^{\text{mm}}$	Cylinder $4 \times 6^{\text{mm}}$	
5.4	8.33	6.68	1.25
21.5	9.78	7.87	1.24
107.5	11.4	9.12	1.25
427.5	12.38	9.8	1.26
1252.5	12.62	10.03	1.26

Volts/cm	Cylinder		Ratio
	$3 \times 4.5^{\text{mm}}$	$3 \times 4^{\text{mm}}$	
5.43	9.02	3.87	2.3
22.5	10.68	4.37	2.4
109.5	12.63	5.25	2.4
432.5	13.6	5.63	2.4
1297.5	13.83	5.77	2.4

As before, the ratio of the currents is constant, as would be expected if the ions are formed in columns.

(e) The active deposit from thorium was also used as an ionizing agent. This was obtained in the usual way by putting thorium hydroxide in a closed metal dish, through the top of which a small brass plug was placed. The containing vessel was charged positively and a difference of potential of about 300 volts was maintained between the vessel and the plug.

The deflections were corrected for the decay of the excited activity.

The plug was exposed for different lengths of time and the following data were obtained :

Parallel Field.

Active deposit 3.5 cm from the middle of the chamber.

Volts/cm	Current		Ratio of Currents
	27 hrs. Exposure	51 hrs. Exposure	
5.3	1.62	2.16	1.33
21.8	1.82	2.37	1.3
104.8	1.95	2.68	1.37
488.8	2.09	2.91	1.39
1013.8	2.17	3.0	1.38

The activity was tested at two different times during its decay with the following results :

Parallel Field.

Active deposit 3.5 cm from the middle of the chamber.

Volts/cm	Current		Ratio of Currents
	65 hrs. Exposure	After 6.5 hrs.	
5.25	1.82	0.94	1.93
21.8	2.0	1.12	1.8
102.5	2.28	1.15	1.98
413.8	2.39	1.27	1.88
1036.0	2.40	1.29	1.86

The ratio is again constant when the field is applied parallel to the path of the α particle. The above deflections are not corrected for ionization due to the β and γ rays of thorium B, but this is so small that it will have no appreciable effect.

Experiment, therefore, seems to justify the assumption that in the case of ionization by α rays, ions are formed in columns along the path of the α particle. These columns are not broken up by the parallel field, but are when the field is at right angles to the path.

III. *A Theoretical Expression for the Saturation Curve.*

A theoretical expression for the saturation curve may be obtained as follows, on the hypothesis of the ions being formed in columns along the path of the α particle and a uniform distribution of ions in the columns.

Let N be the number of positive ions
generated by one α particle
in the chamber.

n_0 be the number of positive ions per c.c.

a be radius of a column.

b be depth of ionization chamber.

The time for an ion to go from any position, x , to the top plate is given by

$$t = \frac{b - x}{k \bar{X}} \quad \text{where } k = \text{mobility of the ion} \\ \text{and } \bar{X} = \text{electric force.}$$

Limiting time for any ion to have a chance to recombine is

$$^{1/2} \frac{b}{k \bar{X}} \quad \text{since half of the ions are} \\ \text{going each way.}$$

Limiting time during which an ion at x can recombine is

$$^{1/2} \frac{b - x}{k \bar{X}}$$

Since the α particle passes through the chamber almost instantaneously, the ionization is over immediately

and
$$-\frac{dn}{dt} = an^2$$

whence
$$\frac{1}{n} - \frac{1}{n_0} = at.$$

Therefore, for an ion which starts at x , the final density n_x , that is the number of ions per c.c. which will reach the plate, will be given by:

$$\frac{1}{n_x} = \frac{1}{n_0} + a \frac{1}{2} \frac{b - x}{k \bar{X}}$$

The charge per column, reaching the plate, will be:

$$e\pi a^2 \int_0^b n_x dx \\ = \pi a^2 e \int_0^b \frac{2 n_0 k \bar{X}}{(2k\bar{X} + an_0 b) - an_0 x} dx$$

$$\text{or } Q_x = \pi a^2 e \frac{2k \bar{X}}{a} \log \frac{2k \bar{X} + \frac{a}{\pi} N}{2k \bar{X}}; \quad \left\{ \begin{array}{l} \text{Since} \\ N = \pi a^2 n_0 b \end{array} \right.$$

where Q_x = charge per column reaching the electrode for a field $\bar{X}$.

Now let $S = \pi a^2$ = cross section of a column and $g = \frac{2k \bar{X}}{a}$;

The above expression reduces to

$$Q_x = e g s \log \left(1 + \frac{N}{gs} \right) \text{----- (B)}$$

If columnar ionization is to explain completely the lack of saturation obtained when a gas is ionized by α particles, the theoretical curve should fit the experimental curve.

Comparison of the Experimental Curve with that given by Equation (B).

Volts / cm.	Current obtained by experiment with the parallel field. Source 2.6 ^{cm} from chamber.	Current calculated from Equation B, made to fit experimental curve at 0.25 volts / cm. and at saturation.
0.25	1.70	1.70
0.75	4.58	3.44
2.02	6.66	5.73
4.80	7.79	7.90
10.13	8.28	9.45
20.75	9.00	10.48
42.00	9.49	11.10
105.75	10.49	11.46
209.50	10.91	11.67
419.50	11.21	11.72
840.50	11.43	11.75
1260.75	11.80	11.77

For curve see fig. 6.

It is seen from the data or from the curves, fig. 6, that except for a potential gradient below 5 volts / cm., the theoretical curve lies above the experimental and approaches saturation faster. Calculations were made for several curves and the above was always found to be the case.

In the ionization chamber used (the ordinary Bragg chamber), the lines of electric force would not be strictly parallel to the path of the α particle so that there would be the combined

effect of the field resolved along and at right angles to the path of the α particle and less recombination might be expected with small differences of potential between the plates.

FIG. 6.

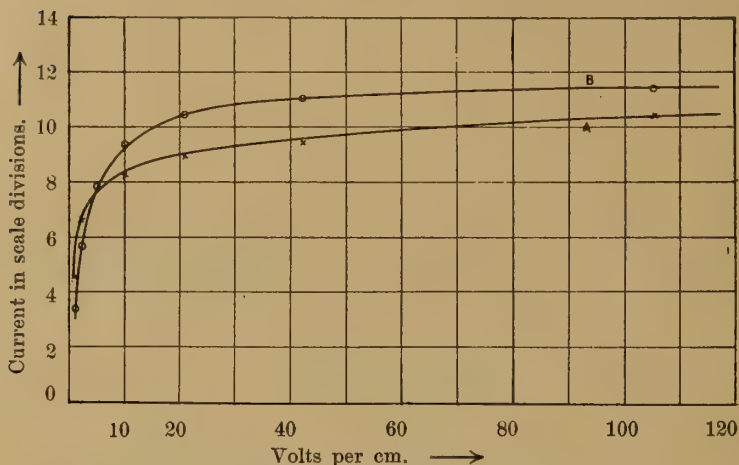


FIG. 6.—A, Experimental curve. B, Calculated curve.

This suggested experiments in which the field would be strictly parallel to the trajectory of the α particle.

IV. *To Test the Effect of Inclination of the Columns.*

For these experiments the ordinary Bragg chamber, used above, was replaced by an ionization chamber consisting of a spherical brass cap of radius 3^{cm} for an upper plate, a spherical cap of wire gauze, radius 2.6^{cm} , for the lower plate of the ionization chamber. This with another spherical gauze cap, radius 2.2^{cm} , formed a second ionization chamber which prevented any stray ions from getting into the ionization chamber proper. The caps were placed 4^{mm} apart. The radio-active source was placed at the center of the spheres of which the caps were a part and only a small pencil of rays was used.

The curves obtained with the spherical chamber, in which the field was always parallel to the path of the α particle, differ very little from those obtained with the Bragg chamber; however they do show slightly more recombination at low voltages, which would be expected. The experimental curve was found to lie below the calculated curve except when an intense electric field was applied.

The explanation of the discrepancy between the experimental curve and that given by the equation is not, therefore, the lack of parallelism between the field and the columns.

This discrepancy may be due to the fact that in the theory above given, it was assumed that uniform distribution of the ions existed in the columns themselves, which is probably not the case. It would be expected that the density of ions would be greater along the axis of the column and would fall off with the distance according to some law, which, if known, would give a theoretical curve, that might more nearly and perhaps exactly fit the experimental curve.

On the other hand, it is quite possible that "initial recombination" (in the sense used by Bragg) may account for part of the lack of saturation, and that the final explanation may require both the "initial recombination" and "columnar ionization" hypotheses.

V. *Comparison of the curves obtained when the ions are produced at different parts of the range of the α particle.*

Since the velocity of the α particle increases as the distance from the source decreases, it is probable that the ejected electron would be sent farther away from its parent molecule when the ionizing source is near the chamber than when it is farther away; that is, the greater the velocity of the ionizing α particle, the greater the velocity of the ejected electron.

If this be true, it would be expected, according to Bragg's initial recombination hypothesis, that the amount of recombination would be greater when the ions are produced in the part of the range where the velocity of the α particle is less.

According to the hypothesis of columnar ionization, recombination would be greatest in the part of the range where the greatest ionization per column is obtained.

The following data were obtained with the source at different distances from the ionization chamber:

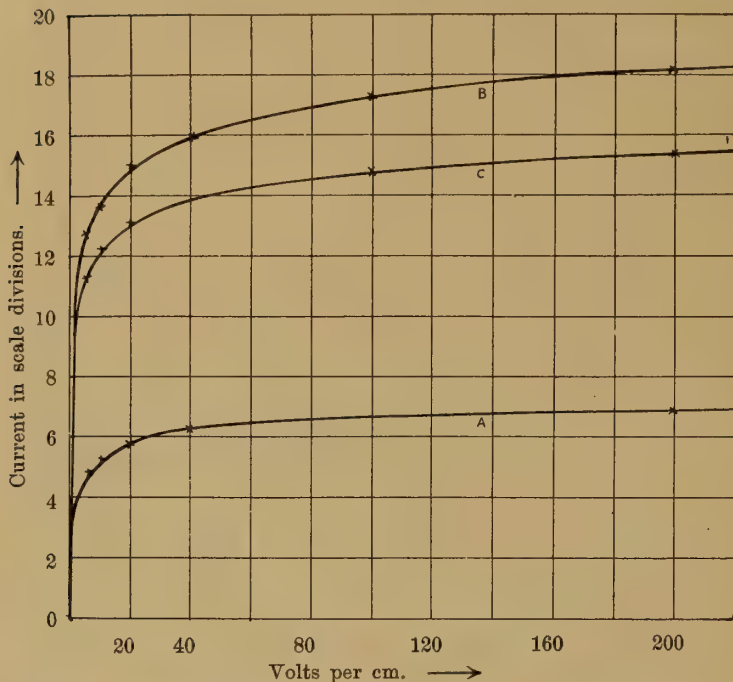
Parallel Field.

Volts/cm.	3.5cm		2.6cm		1.9cm	
	Current	% lack	Current	% lack	Current	% lack
5	4.95	35.9	12.77	33.9	11.35	30.2
10	5.37	30.5	13.67	29.25	12.35	24.1
20	5.87	24.2	15.10	21.8	13.15	19.2
40	6.32	18.6	15.95	17.4	13.95	14.3
100	6.77	12.4	17.45	9.7	15.0	7.8
200	7.15	7.5	18.35	5.0	15.45	5.0
400	7.55	2.3	19.15	1.9	16.0	1.7
800	7.70	0.6	19.32	0.0	16.27	0.0
1200	7.75	0.0	----	----	----	----

For curves see fig. 7.

Volts/cm.	Per cent lack of saturation		
	Dist. 3.5cm	2.6cm	1.9cm
5	35.9	33.9	30.2
10	30.5	29.2	24.1
20	24.2	21.8	19.2
100	12.4	9.7	7.8
400	2.3	1.9	1.7

FIG. 7.

FIG. 7.—A, Source at 3.5cm . B, Source at 2.6cm . C, Source at 1.9cm .

It will be noticed that with the polonium 3.5cm from the middle of the ionization chamber, that is, nearly out of range, the percentage lack of saturation is greatest; at 1.9cm it is least, and at 2.6cm an intermediate value is obtained.

Assuming Bragg's initial recombination hypothesis, this can be explained as follows: The electrons emitted in the act of ionization would be sent farther away from the parent molecules when the source is 1.9cm from the ionization chamber than when the distance is either 2.6cm or 3.5cm . The electrons would thus have a greater chance of getting out of the sphere of influence of the remaining positive ions, with the ionizing source at 1.9cm from the chamber, than in either of the other cases.

On the hypothesis of ionization in columns, it would be expected, since the density of ionization is greater when the polonium is 2.6^{cm} from the chamber, that recombination would be greater. Experiment shows greater recombination with the ionizing source at 2.6^{cm} than at 1.9^{cm}, but less recombination than when it is at 3.5^{cm}. However, when the source is 3.5^{cm} from the ionization chamber, some of the α particles (those sent off at angles of from 23.2° to 26.6° with the vertical) do not enter the chamber at all, and most of the ions in the chamber are formed by the α particles which are sent off, making very small angles with the vertical. The columns thus made would be very little broken up by the component of the electric force at right angles to the path of α particles, since this component would be small.

When the source is 2.6^{cm} or 1.9^{cm} from the middle of the chamber all of the α particles cross the ionization chamber, and the perpendicular component of the electric force might have an appreciable effect upon the recombination of ions, since the columns would be more or less broken up.*

Data obtained with the perpendicular field.

Volts/cm.	3.2 ^{cm}		2.6 ^{cm}		2.3 ^{cm}	
	Current	% lack	Current	% lack	Current	% lack
2	8.75	55.3	11.98	59.0	11.1	58.9
4	11.19	42.8	15.95	45.4	15.23	43.7
10	14.1	28.5	20.76	29.3	19.65	27.3
20	16.05	18.0	23.8	18.5	22.43	17.1
40	17.87	8.7	26.4	9.6	24.6	9.05
80	18.6	4.96	27.85	4.6	25.93	4.1
120	19.1	2.4	28.65	1.9	26.6	1.7
200	19.5	0.36	29.08	0.41	26.95	0.37
1000	19.57	0.0	29.2	0.0	27.05	0.0

For curves see fig. 8.

Mean value of % lack of saturation from several curves.

Volts/cm	Dist. 3.2 ^{cm}	Dist. 2.6 ^{cm}	Dist. 2.3 ^{cm}
2	55.6	59.6	58.3
4	43.3	45.9	44.0
10	28.0	30.0	27.9
40	9.1	10.3	8.8
80	4.8	5.1	4.0

By comparing the lack of saturation at the distances given in the above table, it will be seen that more recombination

* A better test would have been possible if α particles of longer range than those from polonium had been used, but the thorium I had was too weak and Ra. C decays too rapidly for saturation measurements, which take considerable time.

takes place when the source is 2.6 cm from the chamber than in either of the other cases.

This is as would be expected on the hypothesis of ionization in columns. At 2.6 cm the density of ions in the columns is greatest, and therefore greater recombination would take place. With the source at 2.3 cm from the chamber the ionization is a little less than at 2.6 cm ; that is, the density of ions in the columns is slightly less and the percentage lack of saturation is correspondingly smaller. With the source at 3.2 cm the current is about two-thirds that obtained with the source at 2.6 cm or 2.3 cm .

FIG. 8.

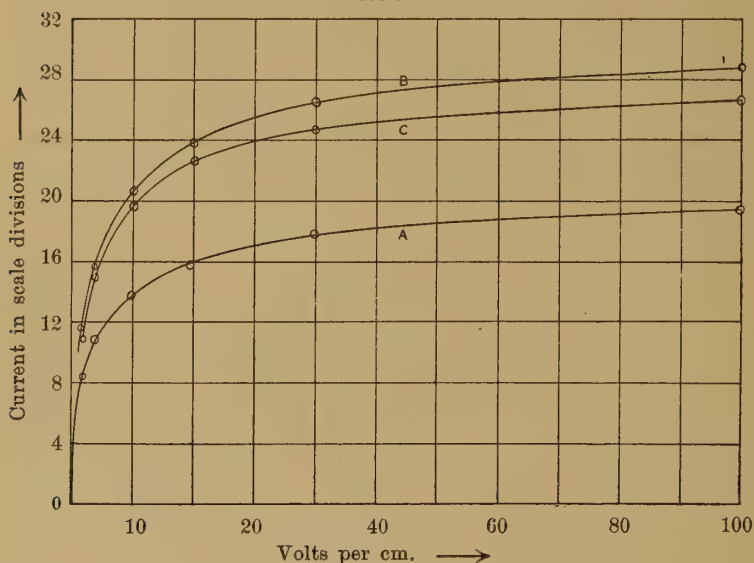


FIG. 8.—A, source at 3.2 cm ; B, source at 2.6 cm ; C, source at 2.3 cm .

This is due to the fact that some of the α particles just barely enter the chamber because of being shot off at relatively large angles with the vertical.

On the other hand, the initial recombination hypothesis of Bragg fails to account for the differences in the experimental curves obtained at different parts of the range, when the electric field is applied at right angles to the path of the α particle.

The velocity of the α particle is greatest with the source at 2.3 cm , least with the source at 3.2 cm , and has an intermediate value at 2.6 cm . The per cent of the ions recombining should therefore be least at 2.3 cm , greatest at 3.2 cm , and have an intermediate value at 2.6 cm , which is not the case.

Again, the effect of initial recombination, if it exists, should be the same whether the field is applied along the path of the α particle or at right angles to it. Experiment shows that the saturation current is obtained with a potential gradient of about 200 volts/cm. between the plates of the ionization chamber, while from 1200 to 1500 volts/cm. are necessary for saturation with the parallel field.

The results of the experiments with the ionization produced at different parts of the range of the α particle seem to show that neither initial recombination, nor the hypothesis of ionization in columns along the path of the α particle, completely accounts for the lack of saturation obtained by experiment. Initial recombination fails when the field is at right angles to the path, while columnar ionization does not entirely account for the recombination obtained with the parallel field.

Here again it is seen that both hypotheses may be needed to completely explain the lack of saturation experimentally found.

VI. *Comparison of Curves obtained at different Pressures.*

Bragg and Kleeman* found that for a gas ionized by α rays, saturation was obtained at a lower potential gradient when the pressure of the gas was decreased. This is as would be expected if initial recombination takes place. At higher pressures the ejected electron might not get out of the sphere of influence of the parent molecule before it is stopped by encountering another molecule; but as the pressure diminishes the mean free path of the electron is increased, and the ejected electron is then able to get farther away from the positive ion and hence initial recombination would occur less frequently.

According to the hypothesis of columnar ionization, as the pressure is diminished the density of ionization in the columns would be diminished and the amount of recombination would be less. Thus it is seen that either hypothesis might explain the results obtained by experiment.

Data obtained at different pressures:

Parallel Field.

Source 4.3 cm from the middle of the chamber.

	Pressure mm. mercury	Volts / cm.	Current	% lack sat.
A	544.7	5	10.4	19.1
		10	10.9	15.2
		20	11.45	10.9
		40	11.83	7.9
		100	12.5	2.7
		200	12.75	0.8
		400	12.77	0.6
		800	12.85	0.0

* Bragg and Kleeman, *Phil. Mag.*, xi, 1906.

	Pressure	Volts / cm.	Current	% lack sat.
B	354.	5	7.07	9.2
		10	7.21	7.4
		20	7.24	7.1
		40	7.6	2.5
		100	7.76	0.4
		200	7.79	0.0
C	224.	5	3.97	5.5
		10	3.99	5.0
		20	4.06	3.4
		100	4.11	2.1
		400	4.20	0.0

For curves see fig. 9.

FIG. 9.

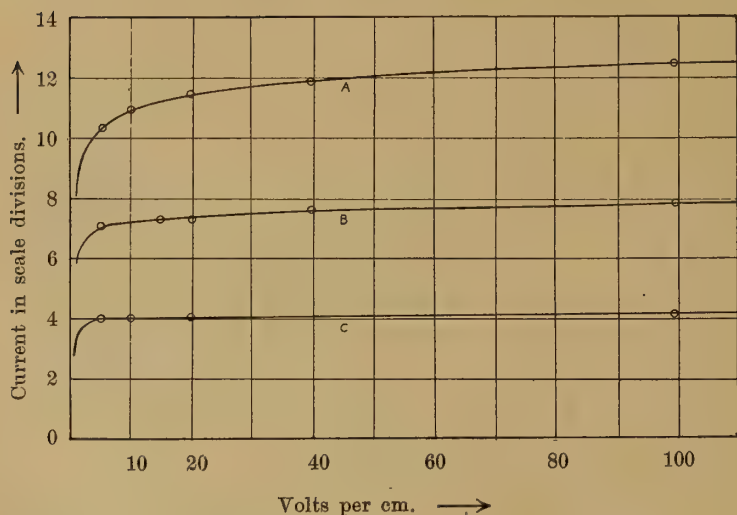


FIG. 9.—A, Pressure of 544.7^{mm} Hg. B, Pressure of 354.0^{mm} Hg.
C, Pressure of 224.0^{mm} Hg.

Source 9^{cm} from the middle of the chamber.

D	224.	5	5.34	5.7
		10	5.5	2.8
		20	5.53	2.3
		100	5.66	0.0
		400	5.66	0.0

	Pressure mm. mercury	Distance from chamber	% lack saturation at different voltages		
			5	20	100
A	544.7	4.3	19.1	10.9	2.7
B	354.0	4.3	9.2	7.1	0.4
C	224.0	4.3	5.5	3.4	2.1*
D	224.0	9.0	5.7	2.3	0.0

* The large value is probably due to an experimental error.

4.3^{cm} at 544.7^{mm} pressure corresponds to 3.08^{mm} at 760^{mm} pressure.

4.3 " 354.0 " " " 2.0 " 760 "

4.3 " 224.0 " " " 1.27 " 760 "

9.0 " 224.0 " " " 2.65 " 760 "

In cases A, B, and C, the percentage lack of saturation decreases as the pressure is diminished, which would be expected on either hypothesis.

In addition to the direct effect of diminishing the pressure there is an indirect effect due to the change in range of the α particle-producing ions. Since the range varies inversely as the pressure, diminishing the pressure and keeping the radioactive source at a fixed distance (4.3^{cm}) from the chamber is equivalent to bringing the source nearer the chamber. This indirect effect is small, however, compared with the effect of decreasing the number of molecules of gas in the chamber.

It is of interest to see how the curve represented by the equation, $Q_{\bar{x}} = egs \log \left(1 + \frac{N}{gs} \right)$, which was based upon

the hypothesis of columnar ionization and a uniform distribution of ions within the columns, compares with the curves experimentally obtained at reduced pressures.

To make this comparison the values of gs were found, which would make the equation fit the experimental curve (pressure 761^{mm} mercury) at different potential gradients applied.

Values of $gs = \frac{2k\bar{X}}{a} \pi a^2$ were then calculated for pres-

sures of 354^{mm} and 224^{mm} of mercury respectively, taking into account the variation of the mobility (k) of the ion, also the variation of a , the coefficient of recombination, with the pressure. The mobility varies inversely as the pressure* for the range of pressure used. The variation of a with the pressure was obtained

by plotting Langevin's values of $\epsilon = \frac{a}{4\pi e(k_1 + k_2)}$, given by J. J.

Thomson† and interpolating for the pressures used.

* Alois F. Kovarik, Physical Review, April, 1910.

† Conduction of Electricity through Gases, by J. J. Thomson (second edition), p. 73.

The results obtained are shown in the following table:

Pressure 354^{mm}.

Volts/cm.	Experimental		Calculated	
	Current	% lack	Current	% lack
5	7.07	9.2	7.24	6.1
10	7.21	7.4	7.33	4.9
20	7.24	7.1	7.46	3.2
40	7.6	2.5	7.51	2.6
100	7.76	0.4	7.60	1.4
200	7.79	0.0	7.71	0.0

Pressure 224^{mm}.

5	5.34	5.7	5.45	3.2
10	5.5	2.8	5.57	1.06
20	5.53	2.3	5.57	1.06
100	5.66	0.0	5.63	0.0

By comparing the calculated with the experimental results, it is seen that the calculated curves approach saturation more quickly than the experimental curves.

In calculating the above curves it was assumed that the radius of the columns was not appreciably affected by the diminution of pressure. If the radius of the column should vary inversely as the pressure, calculation shows that for 5 volts/cm. the lack of saturation reduces to about 1 per cent.

Although the above equation does not fit the experimental curve at atmospheric pressure, it seems allowable to use it to test the effect of changing the pressure, as has been done above.

The fact that the calculated curves for reduced pressures approach saturation more quickly than the experimental curves seems to be another reason for concluding that the effect of general recombination of the ions within the columns does not wholly account for the lack of saturation experimentally obtained, but that initial recombination in the Bragg sense has an appreciable effect.

Summary of Results.

(1) For a gas ionized by α rays the ions are formed in columns along the trajectory of the α particle. These columns are not broken up by a field applied along the axes of the columns and the positive and negative ions have to pass each other in going to the plates of the ionization chamber, while a field at right angles to the columns produces a separation of the positive and negative ions by breaking each column up into two.

(2) With the parallel field, the ionization is proportional to the intensity of the source, even when far from saturation.

(3) The equation obtained by assuming columnar ionization with the ions uniformly distributed within the columns, does not represent the curve experimentally obtained with the parallel field. The experimental curve lies below the calculated curve, except for small potential gradients, when the ordinary Bragg chamber is used.

(4) The lack of agreement between the experimental and calculated results is not due to an inclination of some of the columns in the ionization chamber.

(5) The lack of saturation obtained at different parts of the range, when the field is applied parallel to the path of the ionizing α particle, is not completely accounted for by initial recombination; neither does columnar ionization completely explain the results obtained with the perpendicular field.

(6) The saturation value of the current is obtained more easily as the pressure of the gas is diminished. This would be expected on either hypothesis. However, the results obtained appear to indicate that the lack of saturation is not all due to the effect of general recombination of the ions within the columns.

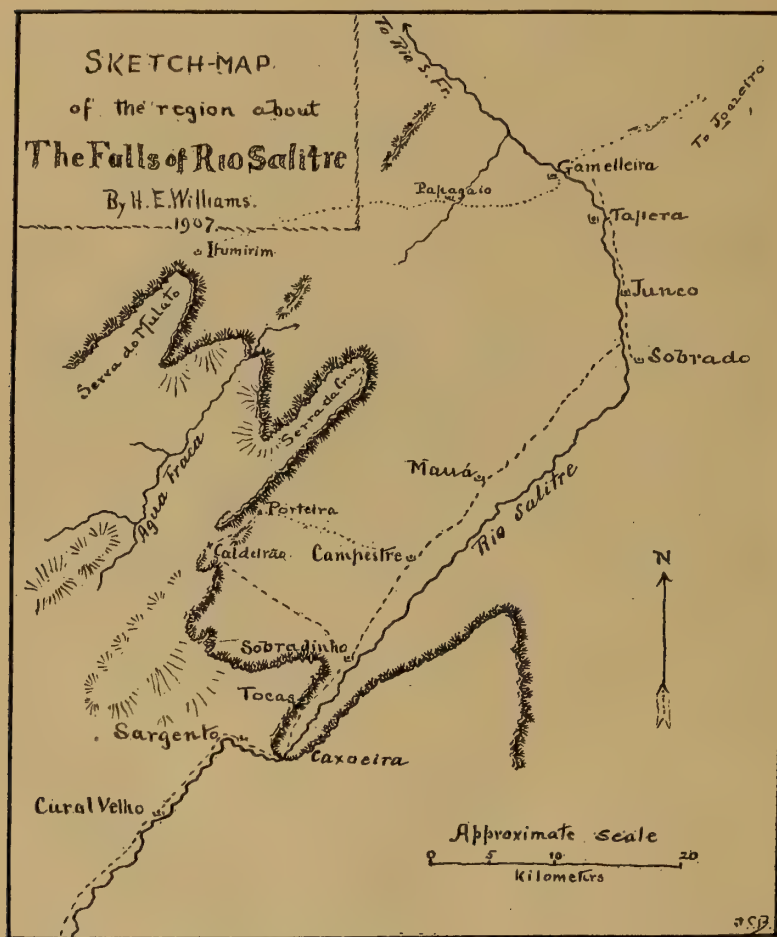
(7) Undoubtedly a considerable part of the anomalous behaviour of the ions produced by α rays (in respect to saturation, etc.) is due to the columnar arrangement of the ions; it is possible that this would be sufficient to account for all the facts if the distribution of the ions within the columns were known. On the other hand, it appears probable that certain outstanding discrepancies may be due to initial recombination.

In conclusion, I wish to express my gratitude to Professor H. A. Bumstead, at whose suggestion these experiments were undertaken, for his many valuable suggestions and kindly interest in the work.

ART. XXV.—*The Geology of the Serra do Mulato, State of Bahia, Brazil* ;* by J. C. BRANNER.

THE city of Joazeiro stands on the banks of the Rio São Francisco at the northern end of the Bahia and S. Francisco railway, 574 kilometers from the city of Bahia. The region in

FIG. 1.



the vicinity of Joazeiro is remarkably flat, with here and there a

* By permission of Prof. O. A. Derby, Director of the Serviço Geológico do Brasil.

distant isolated peak or mountain cluster rising above the otherwise even horizon line made by the low forest growth. The most prominent to be seen from Joazeiro is the Serra do Mulato, which lies about fifty-one kilometers to the southwest. The other peaks or ranges visible from Joazeiro have the rounded or irregular outlines that Brazilian geologists are accustomed to see in mountains of granite or other crystalline rocks, while the top of the Serra do Mulato is flat and the sides are precipitous, suggesting hard, horizontal beds at the top resting upon more yielding ones.

Although the Serra do Mulato is only thirty-two kilometers south of the Rio São Francisco at the village of Tatuhy, it was never visited by a geologist so far as can be learned, until Sept. 1907, when the writer made a trip to its summit in company with Dr. Alfredo de Carvalho, a Brazilian engineer of Pernambuco.

The geology of the mountain is quite simple on the whole, but taken in connection with what was subsequently learned of the region to the south and southwest, it has helped greatly to clear up our conceptions of the geology of a large area in the interior of Bahia regarding which there has long been much doubt and uncertainty.

The region between Joazeiro and the Serra do Mulato is quite flat, and, with the exception of a few small glades and a few cultivated fields, is covered with the short scrubby catinga forests characteristic of the semi-arid portions of the interior of Bahia. Near the Rio São Francisco there are some wide alluvial belts, but for the most part, although the surface is flat, the rocks are either granites, or gneisses, or they are limestones of recent freshwater origin, spread in a thin layer over an old planed down granite surface. These limestones are characteristic of the high-flood plains of the Rio S. Francisco, and will be described in a later paper.

The road from Joazeiro to the Serra do Mulato crosses into Salitre at fazenda Gamelleira, forty kilometers from Joazeiro and thirty-eight from where the Salitre enters Rio S. Francisco. The rocks exposed at that place are slippery green talcose slates standing nearly on end and traversed by many small quartz veins. On the southwest side of the river these slates strike S. 50° W. magnetic; at the fazenda Gamelleira residence the strike of the slates is S. 15° W. magnetic.

About thirty meters west of Rio Salitre at Gamelleira crossing a dike of dark greenish diabase traverses the slates.* This

* Dr. A. F. Rogers has examined specimens of this rock and kindly furnishes the following note in regard to it:

The specimen is a dark-colored basic igneous rock and is referred to a diabase. As seen with a hand lens, it consists of two principal constituents,

dike is about 12 meters wide, but is not traceable any farther toward the north; it extends southwestward up Rio Salitre, however, following the strike of the slates, and widening somewhat in that direction. It was followed only for a distance of 200 meters or so. The following section shows the general geology as it appears along the road from Joazeiro to the fazenda Gamelleira.

FIG. 2.



FIG. 2. Generalized northeast-southwest section, showing the geology between Joazeiro and Rio Salitre.

To the right or north of the road, as the Serra do Mulato is approached, is a long, low and narrow range of hills called the Serra da Batateira. With considerable difficulty one can break and cut his way through the catinga forest and cactus to this range. At its southern end it rises only about twenty-five or thirty meters above the level of the plain. It is composed of very compact quartzites, the beds are clearly defined and stand nearly on end, the dip being 70° east, magnetic. This ridge extends north and northeast some twenty kilometers nearly to the Rio São Francisco. The flat plain about the base of this ridge is strewn with fragments of this same quartzite. About three kilometers to the south is another sharp hill which was not visited, but which appears from a distance to be of the same geologic structure as the Serra da Batateira. In the flat ground between the two ridges the soil has the peculiar snuff-color characteristic of the limestone soils hereabout, and the occasional loose lumps of limestone show that there is here a thin sheet of recent lime-rock, though it is mostly decomposed. Two kilometers west of the Serra da Batateira gneissoid granites are exposed on the plain, and similar rocks crop out along the trail to the ranch house of the fazenda Itumirim, which is about two kilometers north of the base of the Serra do Mulato.

elongate light-colored crystals set in a black matrix. The texture is that of a coarse-grained diabase.

The principal minerals seen in the thin sections are: (1) hornblende, prismatic crystals with the characteristic pleochroism; (2) ilmenite altered to leucoxene; (3) epidote, light-colored irregular mineral with high relief; (4) zoisite, recognized by high relief and Berlin blue interference colors; (5) secondary quartz in clear grains. Besides these there are elongate much altered crystals which probably represent feldspars. The rock is an altered diabase, with scarcely any of the original minerals present.

A. F. ROGERS.

Stanford University, Feb. 9, 1909.

Although the fazenda Itumirim is some thirty kilometers south of the Rio São Francisco, the plain that borders the river extends to the south of the ranch house and ends abruptly against the base of the Serra do Mulato. Hereabout this plain is not alluvial, but is a flat floor of granites and old crystalline rocks cut down apparently by the ancient river itself. So flat is this plain that it is but rarely that a more resisting point rises three or four meters above its general level. In the

FIG. 3.



FIG. 3. Section across the south end of Serra da Batateira, showing the nearly vertical quartzites.

vicinity of the fazenda Itumirim the rocks exposed in place are all banded or sheeted granitoid gneisses. The sheeting dips eastward at an angle of 80° , and the texture of the rocks is remarkably even. Over the surface of these rocks are strewn loose fragments of quartz, most of them sub-angular and somewhat worn by water.

Within two hundred meters of the base of the Serra is a boss-like outcrop of compact and very hard granite that rises two or three meters above the general level of the plain. It has exfoliated somewhat from exposure to the sun, but here and there over this boss, and especially about its base, are well-preserved remnants of waterworn surfaces. These worn surfaces are not pits or depressions such as are often made by aborigines in grinding food, but they are uneven, rounded, smoothed, and polished like the worn hard rock in the bed of the stream. As these bosses stand in the open plain and out of reach of any possible local wearing, it seems clear that they were worn by the São Francisco river itself at a time when its flood waters covered a much larger area than they do at present. The altitude of this plain at the base of the Serra, as determined by aneroid readings carried from the railway station at Joazeiro, is about 400 meters above sea level, and 28 meters above the station at Joazeiro.

Starting up the side of the Serra do Mulato on its north face, the first rocks found in place are some dark-colored crystalline schists. Examined under the microscope, these rocks are found to be composed chiefly of hornblende and epidote.

From this point up to the base of the bare cliffs that encircle the north escarpment of the mountain there are no trails, and

the slopes are covered with a dense growth of catinga forest and cactus difficult to penetrate even under the most favorable circumstances.

On the mountain slope at an altitude of 450 meters the ground in certain localities is strewn with enormous quantities of large, loose, somewhat waterworn bowlders. These bowlders are mostly of the sandstones and quartzites that form the resisting ledge that caps the summit of the mountain. This belt of bowlders suggests the possibility of an ancient water

FIG. 4.



FIG. 4. Serra do Mulato seen from fazenda Itumerim. The flat summit is of Tombador quartzites; the slopes and plain in the foreground are of crystalline rocks.

level. It is here mentioned because at about the same altitude similar boulder zones have been found at other places in the valley of the Rio São Francisco. At 580 meters is an exposure of soapstone or talc that forms a belt running along the north-eastern side of the Serra do Mulato. At 640 meters fragments of dark hornblende schists are strewn over the surface of the mountain slope. At 700 meters the rocks are compact black eruptives resembling diabase. At 740 meters is the base of the vertical escarpment made by the massive quartzites that form the flat top of the mountain.

In order to pass the wall made by these quartzites and reach the summit of the mountain it was necessary to skirt along the east base for about two kilometers. Nowhere in this distance was the actual contact between the quartzites and the underlying crystalline rocks seen; it is evident therefore that the contact is lower down the mountain slope and is concealed by talus and soil.

The necessity for skirting the base of the bluffs afforded an excellent opportunity for examining the rocks and looking for fossils. The quartzites are mostly fine-grained, and nearly all of them show false bedding with remarkable clearness. In the talus slopes below were seen abundant angular blocks of conglomerate, which must necessarily have come from some

part of this series of sediments. The bluff, however, is more than a hundred meters high, and, being inaccessible, could only be ascended at one point on the east side, and no conglomerates were seen at that place. Careful search was made for fossils, but the materials are most unpromising. At a few places there were found some dark angular fragments that suggested plant remains, but if they are such, they are quite unrecognizable. One thin (20 centimeters) bed was found which from its resemblance to a stratum of mud seemed to hold forth some promise. It was so altered, however, that it was quite schistose.

The age of these sedimentary beds cannot therefore be determined at present either from fossils found in them or by reference to any rocks immediately above or below them.

The altitude of the top of the mountain above sea-level is 865 meters; the thickness of the horizontal quartzite beds that cap the summit is something more than 125 meters; the height of the mountain top above the old flood plain at its base is 465 meters.

FIG. 5.



FIG. 5. Serra do Boqueirão and Serra da Cruz seen from the top of Serra do Mulato. The flat summits are Tombador quartzites.

From the top of the Serra one has a good view of the two mountains that lie to the east. These are the Serra do Boqueirão lying next to the Serra do Mulato, and the Serra da Cruz still further to the east. Seen from here, the geologic structure of these two mountains and their relations to the Serra do Mulato are plain and simple. The horizontal quartzites that cap the Serra do Mulato can be followed with the eye along their outcrop to these neighboring mountains, which are capped by this same series of sediments. The Serra do Boqueirão is somewhat lower than the Serra do Mulato, of which it is simply a spur. The valley that separates these two points is a low breached anticline. The Serra do Boqueirão is a synclinal ridge, while between this and the Serra da Cruz is another anticlinal valley. The folds forming these valleys and ridges are gently and clearly defined, and all three of these mountains

are simply the conspicuous spurs of an elevated region lying to the south. From one position on the plain to the northeast as one looks back toward this group of mountains their structural relations to each other can be readily seen. The accompanying profile was sketched from that point.

A later trip made across the region south and west of this group of mountains, and trips made by assistants along the Rio São Francisco, show that the quartzite beds that cap the Serra do Mulato in a similar way form the flat summits of the Serra do Encaibro just east of Sentosé, and of the Serra do Tombador south of Remanso. In other words, the great group of mountains sometimes spoken of as the Serras do São Fran-

FIG. 6.



FIG. 6. Diagrammatic section showing the structural relations of the Serra da Cruz, Serra do Boqueirão, and Serra do Mulato. The crests are of Tombador quartzites; the slopes and plain are of old crystalline rocks.

cisco have these quartzites at the base of a great sedimentary series that is developed in the diamond regions of the interior of Bahia.

It remains to call attention to the relations of the Serra da Batateira to the Serra do Mulato and the other mountains in the latter cluster. That particular range is mentioned here because it represents a type of geologic structure common at many places in the state of Bahia. It seems clear that the Serra da Batateira belongs to a series of very old sediments that have been closely folded and faulted. Whether these sediments are older or newer than the crystalline rocks next to them is not certainly known at present, but the writer is of the opinion that most of the granites are older. The structure, in so far as it was made out in two trips across the region, is shown by the accompanying section. (See fig. 3.)

In the region south of Joazeiro and east and south of Villa Nova are similar narrow, sharp, quartzite ridges with their beds standing nearly on end. These ridges generally have the granites and gneisses on both sides of them. This leads one to conclude that they are the last remnants of a very old series of sediments let down into the older granites by faults, perhaps as suggested in the accompanying section. (Fig. 7.)

The limestones in the section are recent, possibly Tertiary, fresh-water deposits surrounding the ridge, and have been cut out, or were never deposited, along the stream courses. The

evidence of the age of these limestones is conclusive, but cannot be presented here.

Conclusions.—The excursion to the Serra do Mulato made it possible to determine the following facts regarding the geology of the region south and southwest of Joazeiro:

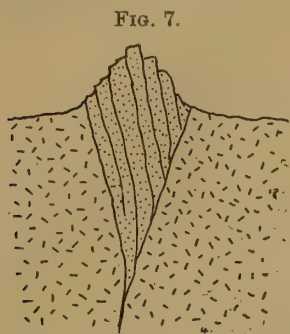


FIG. 7. Section showing the theoretical relations of the ridges of vertical quartzites.

1. The low flat region forming most of the high flood-plain of the Rio S. Francisco is made up of two series of rocks:—I, an older series of crystalline schists, other metamorphics, and eruptives; and II, a series of highly metamorphosed quartzites and schists or shales.

2. Faults have let the old quartzites down into the crystalline rocks here and there, and the upturned edges of these beds form the white walled mountains and hills that are scattered far and wide over the old base-leveled plain. The Serra da Batateira belongs to this type. (See fig. 3.)

3. The flat-topped mountains so common to the west and southwest of Joazeiro, such as the Serra da Cruz, Serra do Mulato, Serra do Encaibro, and the Serra do Tombador south of Remanso, are formed by approximately horizontal beds of Paleozoic quartzites which rest directly upon the old crystalline series.

4. This series of quartzites was later traced up the Rio São Francisco, southward across Rio Salitre at the falls, and farther south to the region about Jacobina. It usually forms a bold escarpment.

5. On account of this series of quartzites forming the Tombador range west of the city of Jacobina, it has been named the Tombador series.

6. No recognizable fossils have thus far been found in these Tombador quartzites. They are called Paleozoic on account of stratigraphic relations found in the region to the southwest.

7. Limestones cover the higher portions of the elevated flood-plain of the Rio São Francisco.

8. These limestones are of fresh-water origin and of Tertiary and later age.

Stanford University, California.

ART. XXVI.—*An Australian Meteorite*; by L. LAYBOURNE
SMITH.

A METEORITE of particular interest has lately been discovered at Murnpeowie in South Australia. It has been acquired by the Council of the School of Mines at Adelaide for exhibition in the mineral and petrological museum of that institution. The new meteorite is a siderite, and is the fourth find of that class to be credited to the central Australian state. The list now comprises the "Yardea," $7\frac{1}{4}$ lbs.; the "Rhine Villa," $7\frac{1}{2}$ lbs. (described in the S. A. School of Mines Report 1900); the "Arltunga," 40 lbs. (not yet described); and the "Murnpeowie," 2520 lbs.

The discovery was made by some boundary fence repairers working on the Beltana Pastoral Company's Murnpeowie run, at a spot $29^{\circ} 35'$ latitude and $139^{\circ} 54'$ longitude, being about 16 miles N.E. by E. of Mt. Hopeless. The country at the place is flat and devoid of stones. The men thought the meteorite to be an isolated rock, and used to stand on it when scanning the plain in search of their donkeys. One day one of the men struck the stone with a hammer, and was astonished at the bell-like sound which it emitted. With much difficulty they were enabled with chisel and crow-bar to fracture off a small piece, which they forwarded to the School of Mines at Adelaide, which institution has a department where assays of minerals found on the Crown Lands of the State may be made and results supplied to applicants free of charge. On being informed that they had discovered a meteorite, they wrote to me offering to sell their find, with the result mentioned above.

The work of transporting the meteorite to Farina, the nearest point to the railway, was undertaken by two men with a wagon drawn by 26 donkeys. The journey to and from the site of the find, a distance of 278 miles, occupied 27 days. The ground was dug away and the wagon lowered until its floor was level with the surface, and the meteorite then turned over—the donkeys pulling on chains. A careful search was made for further pieces but without success. In the vicinity of the find was a hole which I am of opinion was made by the falling meteorite. This hole was roughly elliptical in shape, with its major axis almost due east and west. It measured 16 ft. 6 in. in length, its greatest width 12 ft., and it was 4 ft. deep. The meteorite was lying a distance of 70 yards from the eastern end of the hole and in the direction of the longer axis. The earth had been thrown out into two ridges extending radially for 15 ft. on either side of the hole. Between the meteorite

and the hole were two smaller indentations. It appears, therefore, that the meteorite travelled from a little north of west, and, having torn up the ground on striking, ricocheted, and came to rest practically on the surface of the ground. It was lying breast uppermost with the heavier end nearest the hole and raised some inches.

From a preliminary examination of the meteorite, I am of opinion that it is an "oriented meteorite," the breast being shown in the photograph (fig. 1). The greatest height is 35 inches,

FIG. 1.



width 47 inches, thickness at the right hand corner 19 inches, left hand corner 9 inches. It tapers off toward the top, where the thickness is 8 inches. The front shows some convexity, whilst the greater part of the back is distinctly concave. The piezoglyphic depressions are particularly well developed. On the front they are comparatively small, the cusped groups measuring 3 to 5 inches in diameter, and some half an inch in depth. Many of the markings are deeper in proportion, and resemble the imprints of an animal's paw in some soft material. On the back of the meteorite the grouped depressions measure from 5 to 10 inches across. The ridge outlining the meteorite is sharp in parts, and shows distinctly the effects of fusion from front to back. Drift markings or striations are only noticeable on the front, and occur as more or less horizontal lines—more pronounced on the right side, where they turn in a downward

direction. The meteorite is covered with a varnish-like coating, reddish brown in color, and on the back where it has been lying on the ground there is also a rougher black oxide incrustation. There are several distinct cracks, caused, no doubt, by sudden heating on entering the atmosphere. The metal is tough, but may be cut with a hack-saw. An etched face indicates a fine brecciated structure, the particles varying

FIG. 2.



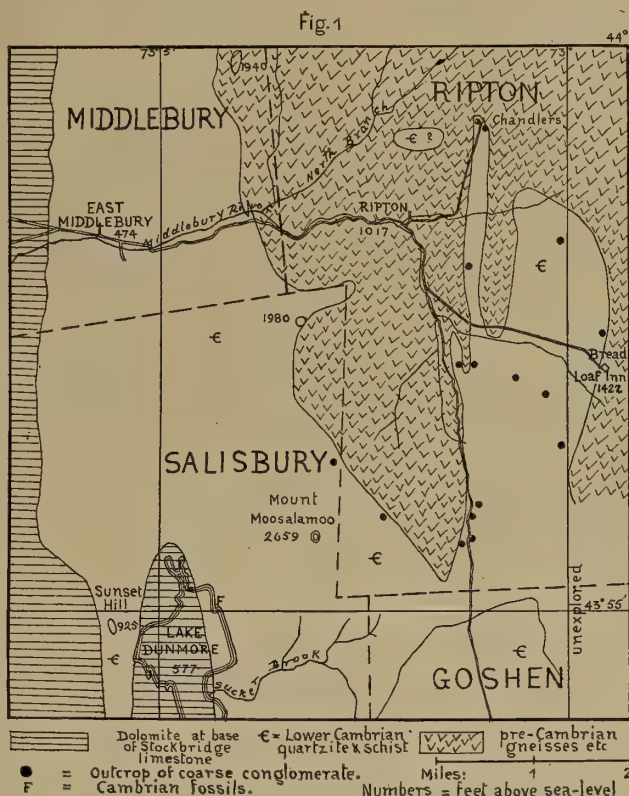
in size, but not exceeding 5^{cm} in diameter in the sections so far polished. The grains are probably kamacite, and are surrounded by fine fissures filled with troilite. They are characterized by brilliant, depressed Neumann lines. The chemical composition has not yet been determined, but is now being undertaken and a careful micro-metallographical examination will also be made. I am making enquiries with a view to finding the probable date of the fall. It appears hardly likely that this took place previous to the erection of the vermin-proof fencing some five years ago. Australian bushmen are very observant, and this isolated stone would not have been overlooked in a position less than half a mile from where the fencers were working. The holes also would fill with sand in a few years. It is probable, therefore, that the Murnpeowie meteorite is a recent arrival.

S. A. School of Mines Museum, March 4, 1910.

ART. XXVII.—*The Cambrian Conglomerate of Ripton in Vermont*; by T. NELSON DALE.*

HITCHCOCK and Hager† represented a strip of “talcoose conglomerate” as beginning a little south of the village of Ripton in Addison Co. and widening northwards in the township of Lincoln, attaining its greatest width, 6 1/2 miles, in Chittenden Co., and extending to the Canada line.

In Ripton it appears as bordered on the east by the granites and gneisses which form the axis of the Green Mountain range and on the west by the quartzite and schist which underlie the marble and dolomite of the Vermont Valley.



In 1903 the writer, in working on the areal geology of the Brandon sheet for the Fort Ticonderoga Folio of the U. S.

* Published by permission of the Director of the U. S. Geol. Survey.

† Report on the Geology of Vermont, 1861, vol. II, map, pl. I. See also vol. I, p. 388, 2d-4th paragraphs and page 346, 2d paragraph.

Geol. Survey, came upon a coarse conglomerate of this formation, continued his study of it in 1904, and revisited some of its outcrops with Mr. Arthur Keith in 1908. A preliminary geologic map of the northwest corner of the Brandon sheet with a half mile strip east of it is shown in fig. 1. The trend of the frontal part of the Green Mountain range is indicated by the altitudes taken from the contour map. The pre-Cambrian gneisses are not differentiated nor are the members of the Cambrian series. Dikes of diabase altered to amphibolite cut the gneisses but are not shown on the map.

The age determination of the Cambrian was confirmed by the writer's discovery in 1903 in an outjutting mass of quartzite on the east shore of Lake Dunmore (point marked F on map) of pteropods determined by Dr. C. D. Walcott as *Hyolithes* of type *communis* and of spines of *Olenellus*. In 1890 Dr. Walcott* mentioned his finding an Ostracod with a marked resemblance to *Nothozoe* in a quartzite boulder on Sunset Hill on the east side of Lake Dunmore, and his having previously found the same fossil in situ in the quartzite east of Bennington associated with *Olenellus* and *Hyolithes impar*.

The quartzite of the west flank of the Green Mountain range appears to be interbedded with schist and this conglomerate forms the base of the formation. The conglomerate was observed at the points indicated on the map, but its most interesting outcrops are that about 1/2 mile E.N.E. of the top of Mount Moosalamoo and also that near the Chandler house, 1 1/4 mile N.E. of Ripton village. The cement of the conglomerate is highly metamorphic, generally a muscovite-quartz schist with more or less magnetite. More than half of the pebbles are blue quartz and the rest are gneiss. At the locality near Mount Moosalamoo the conglomerate lies close to the pre-Cambrian gneiss and has a N. 15° W. strike, a 50° to 80° E. dip, and a minimum thickness of 58 ft. Most of the pebbles range from 3 to 6 inches in diameter but the largest ones measure 10 × 8 in., 14 × 12 × 6 in., 20 × 9 1/2 in., and 23 × 16 × 7 in. This last is shown in fig. 2. At Chandler's the conglomerate strikes N. 67° E. and dips 90°. Here a pebble of blue quartz measures 76 × 57 × 30 in. and over. Its major axis strikes N. 30° E. It might easily be mistaken for a vein. See fig. 3.

Boulders of the conglomerate have been carried southward by the ice sheet into the towns of Goshen and Salisbury. One near the Dutton brook schoolhouse, 4 1/4 miles south of the Ripton-Goshen line, contains pebbles to 8 × 6 in. Another boulder, 20 × 10 ft., in Sucker brook about 1 1/4 mile S. 10° W. from the top of Mount Moosalamoo, consists of micaceous quartzite containing three beds of conglomerate to a foot thick,

* U. S. Geol. Surv., Tenth Ann. Rept., Part I, p. 268.

the larger pebbles of which measure 12 to 15 inches across. No glacial striæ were made out on any of the pebbles.

A number of pebbles from these various localities were studied microscopically and fall into these groups: Blue quartz; biotite granite (medium-coarse); biotite-muscovite granite (fine); biotite granite or biotitic quartz monzonite (fine); mus-

FIG. 2.



FIG. 2. Beach pebbles of pre-Cambrian gneiss and blue quartz weathered out of Lower Cambrian metamorphosed conglomerate on the east spur of Mount Moosalamoo, 1/2 mile E.N.E. of top, in Ripton, Vt. Sledge 30 inches long. Largest pebble $23 \times 16 \times 7$ inches (gneiss).

covite granite or muscovitic quartz monzonite (fine); muscovite granite-gneiss (fine); aplite-gneiss, pyritiferous (fine); quartzite, two small pebbles from locality near Mount Moosalamoo.* Both quartzite and igneous rock pebbles contain rhombs and irregular plates of a ferruginous carbonate passing into limonite, which are also characteristic of the pre-Cambrian gneisses about Ripton.

As to the origin of these pebbles: With the exception of the quartzite and the aplite-gneiss all these rocks have already been found in situ in the pre-Cambrian area shown in fig. 1. The blue quartz is identical with that of a mass cut by the

* Determination of aplite by E. S. Larsen, Jr., of U. S. Geol. Survey, that of quartzite confirmed by him.

Middlebury River $1\frac{1}{2}$ mile west of Ripton village, which, judging from its relation to other outcrops on the hillside south, probably measures about 500 ft. from east to west and 1500 ft. from north to south, tapering out at the north. Some parts of this blue quartz are schistose, but a thin section of that shows no feldspar but a matrix of sericite carrying large particles of quartz containing a few biotite scales. If the sericite is altered

FIG. 3.



FIG. 3. Beach pebble of blue quartz of pre-Cambrian origin in schist and conglomerate of Lower Cambrian age near Chandler house in Ripton, Vt. Size $76 \times 57 \times 30$ inches. Sledge and bag rest on conglomerate. In distance central range of Green Mountains.

feldspar, then we have to do with a very acidic granite-gneiss, but most of the blue quartz rock is probably of pegmatitic origin. Fine-grained quartz monzonite crops out at points $1\frac{1}{4}$ miles west and $1\frac{3}{4}$ miles N.E. of Ripton village.

Conclusion: The generally rounded or discoid form and the unstriated surfaces of these pebbles from the Cambrian conglomerate point to their having been formed on a beach, and their magnitude points to their local origin, which is corroborated by the occurrence of identical gneisses, quartz monzonite and blue quartz in the underlying or adjacent pre-Cambrian. The quartzite pebbles show the existence of Algonkian sedimentary rocks on the Green Mountain range. These large beach pebbles thus take us back to the time of the Cambrian sea as it advanced over the very slowly subsiding pre-Cambrian land-mass of central Vermont.

Pittsfield, Mass., June 21, 1910.

ART. XXVIII.—*Some Tests upon the Synthetic Sapphires of Verneuil*; by ALFRED J. MOSES.

VERNEUIL describes briefly* synthetic sapphires of "beautiful color" made in his oxyhydrogen furnace by adding to the alumina "1½ per cent. of magnetic oxide of iron and ½ per cent of titanio oxide." The resulting ovoids or cone-shaped masses are said on authority of Wyruboff to be "unique crystals, uniaxial, negative, weakly doubly refracting and with, consequently, the optical properties of the natural sapphire."

An examination of material sent by L. Heller & Son consisting of one dozen of the cut stones and one of the uncut cone-shaped masses yielded some exact figures which are here stated.

Three analyses were made by my assistant, Dr. M. A. Lamme. No. 1—Transparent fragments of the uncut cone, not including either the blackish scoria-like material at the apex or the thin brownish layer at the base. No. 2—Two small cut stones, one deep blue, one pale blue in color. No. 3—One deep blue cut stone.

	1 Weight 0.4070 gm.	2 Weight 0.3990 gm.	3 Weight 0.2966 gm.
Al ₂ O ₃ -----	99.84	99.85	99.83
Fe ₂ O ₃ -----	trace	trace	trace
TiO ₂ -----	0.11	0.12	0.13
SiO ₂ -----	none	none	none
	99.95	99.97	99.96

The material was crushed in a diamond (steel) mortar, through a 100-mesh screen and all particles of steel removed by the repeated use of a strong magnet. It was then fused with KHSO₄. The alumina obtained was re-fused for a colorimetric determination of TiO₂.

There are few recorded analyses of true sapphire and I believe none showing either chromium or titanium. The coloring matter suggested by these analyses is iron. For instance:

	India†	Ceylon‡	Ceylon‡
Al ₂ O ₃ -----	97.51	99.33	99.26
Fe ₂ O ₃ -----	1.95	0.92	0.97
SiO ₂ -----	0.80	----	----

* Comptes Rendus, Jan. 17, 1910.

† J. Lawrence Smith, this Journal (2). xi, 54, 1851.

‡ Karl Pfeil, Centralblatt f. Min., 1902, p. 145.

The following physical and crystallographic characters were determined by me:

Hardness 9, that is less than that of carborundum, greater than that of chrysoberyl and not noticeably different from that of the natural sapphire. In grinding it was very little affected by emery.

Specific gravity as determined upon one polished fragment of the cone and upon two of the cut stones.

Cone	3.988
Cut stone	4.01
Cut stone	3.977

Natural sapphire is stated by Bauer (*Edelsteinkunde*, p. 319) to have the specific gravity of 4.08.

FIG. 1.



Parting. Although the finely crushed fragments of the cone examined under the microscope showed in general only irregular to conchoidal fracture, some of the particles showed a development of sets of parallel-plane separations at angles

near 90° . These are shown in the accompanying cut with a magnification of 225 diameters and strongly suggest the planes of separation parallel $10\bar{1}1$ described by Bauer* in true sapphire for which the angle is $93^\circ 59'$.

Double Refraction and Indices of Refraction.—Sections were made from the uncut cone and polished and the “tables” of four of the larger cut stones were used directly. For each surface the direction yielding the largest and smallest indices was determined by trial. The instrument used was the latest form Abbé crystal refractometer, the liquid a solution of sulphur in methylene iodide with $n = 1.784$, and the temperature 20°C . The sodium flame was used.

	ω	ϵ
Surface parallel cone axis	1.7678	1.7600
Surface perpendicular cone axis	1.7684	1.7600
Cut stone table	1.7676	1.7580
“ “ “	1.7678	1.7598
“ “ “	1.7683	1.7592
“ “ “	1.7684	1.7598

We may, therefore, take as the most probable values for synthetic sapphire the averages

$$\omega = 1.7680 \quad \epsilon = 1.7594 \quad \text{and} \quad \omega - \epsilon = .0086$$

For natural sapphires the following results with sodium light are recorded:

	ω	ϵ	$\omega - \epsilon$
Sapphire from Ceylon (Brauns)	1.7693	1.7610	.0083
Sapphire from Burmah (Melzer)	1.7692	1.7609	.0083

Pleochroism.—Very noticeable with the deeper blue stones, ω indigo blue as in true sapphire, ϵ pale blue but without the greenish and yellowish tints often noticed in the true sapphires.

Interference Figure and Optic Axis.—In finely crushed material a negative apparently uniaxial interference figure was obtained on several different grains.

Two surfaces were then polished on the conical mass approximately at right angles to each other, the direction in each determined which yielded the smallest extraordinary index and a section about 2^{mm} thick was made as nearly as possible parallel to the plane of these two directions, such a section being approximately perpendicular to the optic axis of the cone. The section yielded a distinct, many ringed, but eccentric interference figure optically negative. A thinner section ground until the figure was nearly central showed anomalies, being apparently true uniaxial in one portion but

* Zeitschr. d. Geol. Ges., xxvi, 192, 1874.

definitely biaxial in others with the orientation of the axial plane varying. Similar optical behavior is recorded for some crystals of true sapphire. The optic axis was not coincident with the cone axis but was at about 40° to it.

While, strictly speaking, the crystalline system is not determined, the recorded tests show that the cone-shaped mass is an anhedral crystal with all determinable characters closely resembling those of natural sapphire.

ART. XXIX.—A *Cretaceous Lycopodium*; by EDWARD W. BERRY.*

Fossil remains of club mosses are exceedingly rare especially in beds of Mesozoic age and such as have been described have nearly all been based upon fragments of foliage not at all conclusive in character, since such fragments may, and usually are, found to be referable to some conifer when additional or more complete material subsequently becomes available.

A number of forms have been described from the Paleozoic which show some of the fructification characters and which ally these ancient forms with the modern *Lycopodiums*. These are usually referred to the genus *Lycopodites* of Brongniart. In post-Paleozoic rocks, however, not a single specimen showing the character of the fructification, and consequently referable with certainty to *Lycopodium*, has been discovered, at least to the writer's knowledge.

Hence the following species is of considerable interest. The remains are in the form of crushed impressions preserved in a clay lens in the Upper Cretaceous sands near Middendorf, in Chesterfield County, South Carolina. These beds are of early Upper Cretaceous age and contain an abundant flora which stamp them as about the same age as the Magothy formation of the more northern Atlantic Coastal Plain, or according to European standards, probably corresponding with the Turonian. These lycopodiaceous remains consist of fruiting spikes or fragments of spikes to the number of 17 specimens, and while they leave much to be desired in the way of preservation, enough is discernable to stamp them as closely allied to the existing species of *Lycopodium*. These spikes are not badly crushed as is shown by fig. 1, which is a photograph of one of the largest ones found. They are made up of a central stout axis, bearing numerous rows of close set but poorly imbricated bracts, each bract apparently subtending a large spheroidal sporangium.

The spikes show considerable differences in size, the shorter and smaller ones being less crowded and somewhat lax in appearance. The largest one collected is 5^{cm} in length by 5^{mm} in diameter and is nearly complete. The average dimensions are, however, somewhat less than this. The bracts have a narrow acute apex, a broad laminar somewhat thickened portion, with a truncate or slightly cordate or retuse base and a short peduncle. The margin is entire. Fig. 3 is a drawing of one of these scales as it occurs slightly twisted and flattened out in the clays. Fig. 4 is a diagrammatical drawing of a bract showing the position of the sporangium. Figs. 5 and 6 are diagrammatical sketches of the two modes of appearance of

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the bracts and their sporangia in lateral view, the bract being apparently curved upward in fig. 5 while in fig. 6 it is thickened throughout the laminar portion and turns sharply upward immediately beyond the sporangium. The latter is believed to be the normal form, the other being probably due to the method of preservation. The method of attachment of the sporangia cannot be made out; they are in the axils of the bracts, but whether attached to the axis or to the dorsal face of the bract as the drawings would indicate cannot be determined. It is



FIG. 1.—*Lycopodium cretaceum* sp. nov.

- 1—Photograph of a large specimen, natural size.
- 2—Drawing of small specimen, $\times 5$.
- 3—A single bract, $\times 10$.
- 4, 5, 6—Somewhat diagrammatical drawings of bracts and their sporangia, $\times 10$.

probable that the arrangement is the same as in the modern species, but there is a possibility that they were attached to the bract and this possibility is worth mentioning because of the wide interval between the sporangium and the axis in some of the Paleozoic Lycopodiales.

There is nothing to indicate that these sporangia were not reniform in shape as in the modern *Lycopodium* instead of spheroidal as they appear in the fossils; the character of the base of the bracts would tend to show that they were reniform.

No remains of foliage which can be correlated with these fruiting spikes has been found in association with them or in beds of homotaxial age elsewhere in South Carolina, so that the vegetative character of the species remains unknown. The species may be called *Lycopodium cretaceum*.

Johns Hopkins University,
Baltimore, Md.

ART. XXX.—*New Units in Aero-physics*; by ALEXANDER McADIE.*Pressure.*

SINCE the time of Torricelli and Pascal, measures of atmospheric pressure have been in linear units; i. e., the height of a column of water or mercury in vacuo. The barometer, in English-speaking countries, is read in inches and decimal parts thereof; and in countries where the metric system prevails, in centimeters or millimeters. For example, a standard atmosphere is generally defined as the pressure of a vertical column of pure mercury whose height is 29.92 inches or 760 millimeters, at the temperature of melting ice, in latitude 45° , under normal gravity and at sea level. Evidently then, if one wishes to know the ratio of certain changes in atmospheric pressure occurring from day to day and from hour to hour, variations which are of prime importance to the meteorologist, he must refer the change to some normal or assumed standard height.

For example, a fall or a rise of .75 of an inch would be $\frac{.75}{29.92}$

or, if metric values are used, $\frac{19}{760}$ mm. Again, in expressing

lines of equal pressure, as on the daily weather maps, we draw for differences of one-tenth of an inch; or, if the 2^{mm} gradient is used, .078 of an inch. The method of reduction is cumbersome; and it is doubtful if the average reader of the synoptic charts obtains any clear conception of the actual meaning of pressure variations. The entire process of representing pressure conditions would be much simplified if variations could be given in percentages or permillages of a standard atmosphere. Such an arrangement was suggested by the writer in a paper published in the *Monthly Weather Review* in August, 1908. Dr. W. Köppen* of the Deutsche Seewarte, Hamburg, in March, 1909, modified the proposal, suggesting instead of the sea-level pressure, the new base, the pressure represented by the value one million dynes. In other words, instead of using the pressure indicated by 760^{mm} (29.92 inches), which in force units would be 1,013,303 dynes (obtained by multiplying 1033.291 grams per square centimeter by normal acceleration of gravity 980.65), use a megadyne, corresponding to a pressure of 750.1^{mm} (29.532 inches). This quantity is called a *small* atmosphere (with Bjerknes and Sandström) or a *Bar*.

* See also Köppen's Memoir before the Aerological Congress at Monaco, April, 1909.

Abbreviations corresponding to others in the metric system would be b, db, cb, mb.

The new pressure base is found at a height of 106^{mm} (348 feet) above sea level, a level that is very convenient for many reasons, which cannot be gone into here.

The following short table may be found helpful in connection with the new system :

To convert Pressure into Megadynes (C. G. S. Units).

23 inches	=	·779 mgd.	·1 inch	=	·0033	·01	=	0
24 "	=	·813 "	·2 "	=	·007	·02	}	= ·001
25 "	=	·847 "	·3 "	=	·010	·03		
26 "	=	·881 "	·4 "	=	·014	·04		
27 "	=	·914 "	·5 "	=	·017	·05	}	= ·002
28 "	=	·948 "	·6 "	=	·020	·06		
29 "	=	·982 "	·7 "	=	·023	·07		
30 "	=	1·016 "	·8 "	=	·026	·08	}	= ·003
31 "	=	1·050 "	·9 "	=	·030	·09		

Thus at Denver, elevation 5,291 feet, the mean barometer reading is 24·708 inches. In the new unit this would be ·834 mgd. or 834,000 dynes. At New York, elevation 314 feet, the mean pressure is 29·695 inches, or 1,004,000 dynes. Between the two stations, then, one readily perceives there is a gradient of 170,000 dynes, or in round numbers 17 per cent.

It will also be noted that the new system permits the widest possible range and is entirely suitable for the needs of the investigator at high levels, such for example as in the work done during the past two years with ballon sondes, free balloons and kites. Dr. W. N. Shaw, Director of the Meteorological Office, in a recent paper * on the "Investigations of the Upper Air" uses the new unit (see page 280) and rightly says : "The reason for adopting this unit is that in the examination of the results of the upper air, the actual number of inches or millimeters in the pressure at any level is of little importance, compared with the fraction of the atmosphere that is above or below the level."

It may not be generally known that recent observations have brought out the fact that our atmosphere is practically in two sections, a lower or troposphere and an upper or stratosphere. Below 11 kilometers the atmosphere is in a disturbed condition, convectional currents are well marked, and cyclonic circulations prevail. The decrease of temperature is nearly adiabatic, although at times there are strongly marked inversions. In the stratosphere there is a slight rise in temperature with iso-

* The Free Atmosphere in the Region of the British Isles. M. O. 202, 1909, containing Report by W. N. Davis. See also Report by Gold and Harwood, B. A. A. S. meeting at Winnepeg, 1909.

thermal conditions up to 27 kilometers. Tiesserenc de Bort* has shown that "the stratosphere is lowest in the cyclone and highest in the anti-cyclone, and its level sinks from the equator to the poles. The stratosphere is a region of interlaced currents and small vertical movements."

The term *isothermal* has been applied to the region above 11 kilometers to distinguish it from the lower levels or troposphere in which "the vertical variation of temperature is about 6° C. per thousand meters."† The names advective and convective have also been suggested as indicating the modes of transfer of the air in the two great divisions of the atmosphere.

The work now in progress on the exploration of the upper air and the prevalent interest in aviation open a new era in aerology. The promise of the times is a more definite knowledge of pressures and temperatures at all levels. It is, therefore, of some importance that our present bewildering systems of notation should give way to one international nomenclature. Our present cumbersome and inadequate units should be replaced by others capable of conversion into absolute units and suitable for universal needs. We think the new unit, whereby atmospheric pressure is recorded in dynes, meets the requirements.

Temperature.

Since the time of Galileo temperature has been measured by the expansion of mercury in a glass tube. The unequal expansion is divided into degrees and values are based upon the position of two fiducial points. Without going into the evolution of present thermometric scales, it may be noted that Galileo had a scale of 360 degrees, the lowest point based upon some freezing mixture and the highest representing the warmest day of summer. Fahrenheit had several scales. In the one finally adopted the zero is based on the temperature of the coldest day of the year 1709 in northern Europe. Réaumur used melting ice and boiling water, dividing the distance into eighty degrees. Celsius, using the same points, divided the distance into one hundred degrees, with the zero at the boiling point. This scale is often referred to as identical with the Centigrade scale, but this is a mistake. Linnæus modified Celsius' scale, making the zero indicate the temperature of melting ice and one hundred degrees that of boiling water. This is the widely used Centigrade scale. Concerning the Fahrenheit scale it may be noted that it has practically lost place in scientific usage to-day. Furthermore, in all our thermometric scales the so called fixed points are not truly fixed.

* Report of Aerological Congress at Monaco, 1909. Rotch in Science, vol. xxx, No. 763, p. 193-199, August, 1909.

† Gold and Harwood, B. A. A. S., 1909, p. 32.

These need further definition, and it may be well to emphasize somewhat how both fiducial points wander with change in pressure. We find, for example, on the summit of Mount Whitney* that the boiling point on an average summer day is 86°C. (186.4°F.). Likewise the zero, that of melting ice varies. It is raised by the decrease of pressure. Indeed, throughout the western half of our country and especially in mountain sections the thermometer scale is shortened at both ends. A degree of temperature then is not a constant quantity if the fiducial points are not definitely known. Furthermore even at sea level there are differences of pressure due to passing atmospheric disturbances, and the change is sometimes sufficiently great to cause a variation of several degrees in the boiling and the melting points. But a new thermometer scale is much needed for another reason, and that is to avoid minus signs. Over a large portion of the earth during several months of the year temperatures are expressed by means of a negative sign. In the upper air, temperatures of from -50°C. to -70°C. are not infrequent. To avoid this use of a negative sign it is proposed to record air temperatures hereafter on a scale, the zero of which shall be the absolute or natural zero, 273° below the zero of the Centigrade scale. The change is easily made, and any temperature on the Centigrade scale is readily given its new value by adding 273 degrees. In practice the first figure, 2, can be dropped as the degrees, 200 A. to 299 A., cover temperatures from -73°C. to 26°C.

Thus we have practically obtained the Kelvin or Absolute scale and the temperature is read as it would be given by a constant volume gas thermometer.

$$\begin{array}{l} T \text{ equals } t + 273.10^{\circ} \text{ C.} \\ T \quad \text{ " } \quad t + 459.58^{\circ} \text{ F.} \end{array}$$

It is a scale that is largely independent of the properties of the material used. Dr. Shaw says† that "the use of the absolute as distinguished from the Centigrade scale is becoming increasingly common in scientific publications, not only in regard to subjects connected with very low temperature, such as the liquefaction of gases; but in other work also, on account of its direct application in formulæ connected with thermal radiation, thermodynamics and the gaseous laws, with all of which the investigation of the upper air is closely concerned."

* A small observatory has just been built by the Smithsonian Institution at this point, which is the highest point in the United States, excluding Alaska, 14,502 feet. See paper "Mountain Sites for Observatories," Pub. Astronomical Society of Pacific, vol. xxi, No. 124, Feb. 1909, in which the writer gives data for Mt. Shasta and Mt. Rainier.

† British Meteorological Office, Pub. 202, pages 5 and 6.

Wind.

It seems desirable to abandon the use of compass points in designating wind direction and to use hereafter degrees, starting from true north as the zero point. The new system eliminates the possibility of confusion of the terms east and west and also saves time in trigonometrical work and computing. The air in motion, or wind, will be regarded as flowing in to the center. For example, the wind previously recorded as northeast, because of blowing from that direction, will now be recorded as 45° . Velocities are to be recorded in meters per second.

Humidity.

As at present recorded, the moisture of the air is expressed in terms of relative humidity. This is at best a ratio and means different amounts of water vapor present with different temperatures. The absolute humidity, or weight of vapor in grams, is sometimes given. Likewise the vapor pressure. It would seem best to abandon the relative humidity and hereafter give the weight of water vapor in grams per thousand cubic meters of space. There should also be some means of representing the pressure of saturated aqueous vapor at the given temperature.

Miscellaneous.

There should also be suitable units for recording amounts of solar energy absorbed and radiated; also popular units for hours of sunshine and percentages of the possible. Precipitation should be recorded in millimeters and snow in its water equivalent. Cloud heights and cloud velocities should be given in the metric system.

A few of the new units and symbols employed follow:

F_b	“	equals pressure in units of force, base 1,000,000 dynes
b	“	one megadyne, or <i>bar</i>
db	“	decibar
cb	“	centibar
mb	“	millibar
B_1	“	pressure at 106 meters, equals 750.1^{mm} (29.532 inches)
B_0	“	“ “ sea level, “ 760.0 “ (29.92 inches)
W_1	“	weight “ B_1 “ 1019.8 grams per sq. cm.
W_0	“	“ “ sea level, “ 1030 grams per sq. cm.
H	“	height of homogeneous atmosphere
		above B_1 equals $788,504^{cm}$
T	“	273 C. plus t .
R	“	gas constant for air, “ $2,832,250$

C_p	equals	specific	heat	of	air,	equals	9,804,000
C_v	"	"	"	"	"	"	6,971,750
k	"	$\frac{C_p}{C_v}$	-----	"			1.4062486
A	"	heat	equivalent	of	work	"	.0000002389
l	"	mechanical	equivalent	of	heat		42,683.7
H_c	"	height	of	convective	surface		
T_c	"	temperature	at	H_c			
P	"	specific	weight	of	air	-----	.00129305
P_{av}	"	"	"	"	water	vapor	.00080427

NOTE (added August 10, 1910).

Through the courtesy of Professor Charles F. Marvin and Mr. C. F. Talman, Librarian of the Weather Bureau, the following references have been found, proposing the use of C. G. S. units in measuring atmospheric pressure:

B. A. A. S. 1888 meeting, page 28. A committee of the British Association proposed the use of the *Barad*, pressure of one megadyne per square centimeter.

Monthly Weather Review, vol. xxvi, 1898, page 314, Cleveland Abbe discusses measurement of pressure in standard units of force.

C. E. Guillaume proposed to International Congress of Physicists in 1900, use of megadyne under the name *Barye*; and this was favorably reported by a committee of the Congress. (Travaux, Congr. Int. Phys., Paris, 1900, t. iv, pp. 61-62.)

Sandström and Helland-Hansen in their report on Marine Investigation, dated 1902, used the megadyne and the unit of atmospheric pressure and also for hydrostatic pressure.

Bjerknes and Sandström, in 1906, used the unit *bar* as mentioned by Köppen, Quar. Journ. Roy. Met. Soc., April, 1909.

During the present year Köppen, Shaw, Gold, Harwood, Dines and others used the bar.

ART. XXXI.—*Gageite, a New Mineral from Franklin, New Jersey*; by ALEXANDER H. PHILLIPS.

ATTENTION has been drawn to the probable existence of another new mineral from this locality by Prof. Penfield in his description of leucophœnicite,* but as very little of the same material came to the surface from the mine until the fall of 1909, nothing further was ever done in the matter. For the last six months Mr. R. B. Gage of Trenton, N. J., for whom the mineral now described is named, has been collecting material for an analysis. Through the aid of Col. W. A. Roebling of Trenton, who was willing to sacrifice his best specimen, .04 of a gram of well-crystallized material were obtained, and used by Mr. Gage with the results here given :

			Ratio.	
SiO ₂ -----	24.71	.412		1.49
MnO -----	50.19	.707	} 1.109	
ZnO -----	8.76	.107		4.00
MgO -----	11.91	.295		
H ₂ O -----	[4.43]	.246		.9
	100.00			

Letting R stand for the metallic oxides, the ratio of SiO₂ : RO : H₂O is as 1.49 : 4 : .9, yielding the formula (RO)₈ (SiO₂)₃ .2H₂O. Just how the water is related to the oxides, there was not enough material to determine, as in fact the water in the analysis is determined by difference. A large amount of the burden of error will therefore lie in that portion of the analysis; it is certain, however, that there is considerable water in the molecule. From the empirical formula, gageite would seem to be closely related to leucophœnicite, if not one of the probable series mentioned by Prof. Penfield.

Before the blowpipe the clear crystals assume at once a light bronze color, which darkens on further heating to a deep bronze, or nearly black, but they do not fuse. In the closed tube it yields water with the same change of color. The crystals dissolve at once in warm dilute nitric acid; upon heating this solution after the addition of a little silver nitrate and a small crystal of ammonium persulphate a very distinct permanganate color is obtained; a single small crystal will yield this test.

All the specimens of gageite thus far obtained are from the Parker Shaft. It is well crystallized, the crystals are clear and colorless, with a high vitreous luster, delicate, acicular and hair-like, often radiated and grouped in bundles extending out from

* This Journal, viii, 351, 1899.

the walls of small cavities, not unlike the habit of millerite. It may occur as a matt of interlocking crystals, or fan-shaped groups. Under the microscope the prism angles seem to be well developed, and several of the larger crystals are terminated by a pyramid. While no measurements of the angles have as yet been attempted, it is hoped that the crystalline elements and the important forms may be established in the near future from the material at hand.

The specimens thus far found have been associated with crystalline zincite, green willemite, calcite, while leucophœnicite has always been present, serving as a support for the gageite crystals. The same combination of agencies which produced leucophœnicite has also produced gageite, but as the ultimate product of crystallization.

Princeton, N. J., June 6, 1910.

SCIENTIFIC INTELLIGENCE.

I. CHEMISTRY AND PHYSICS.

1. *Carbon Monosulphide*.—This compound, which is analogous to carbon monoxide, and which would be expected to be a gas, was described by Sidot in 1872 as a remarkably stable red powder produced by the action of light upon carbon disulphide. SIR JAMES DEWAR and H. O. JONES have now, for the first time, made the compound by the use of a chemical double decomposition, using for the purpose nickel carbonyl and thiophosgene. These react in the presence of a solvent, such as dry ether, carbon tetrachloride or chloroform, apparently according to the equation



or rather according to a multiple of this equation, since the product is evidently a polymer $(\text{CS})_x$, because it is a solid rather than a gas. The product thus obtained agrees with Sidot's product in some respects, but it differs from it in some ways. It is a brown powder having a specific gravity of 1.6, but after compression into a solid block it gave the value 1.83. It is practically insoluble in alcohol, ether, benzene, and petroleum ether; it is slightly soluble in carbon disulphide, ethylene dibromide, nitrobenzene, naphthalene and phenol, giving deeply colored, reddish brown solutions. It is not soluble in dilute sulphuric acid, but in the concentrated acid it dissolves, forming a brownish purple solution, the color of which is only slowly destroyed at the boiling point of the acid. Upon dilution with water the solution in sulphuric acid gives a precipitate of the unaltered compound. It dissolves in concentrated nitric acid at ordinary temperature and the color of the solution is only destroyed by long heating. It dissolves in aqueous or alcoholic solutions of ammonia, ammonium sulphide, caustic potash and potassium sulphide, giving deep brown solutions from which acids precipitate it apparently unchanged. When the solid was heated in a high vacuum practically no change took place below 360°C .; at a red heat carbon disulphide was given off, but even after long heating at this temperature the residue, consisting largely of carbon, still contained a considerable amount of sulphur. On heating the carbon monosulphide in a current of dry hydrogen, hydrogen sulphide was produced and the residue was almost free from sulphur.

In a subsequent communication the same authors have described the preparation of what appears to be carbon monosulphide by the action of the silent electric discharge upon carbon disulphide vapor at the temperature of liquid air. At this low temperature a very low boiling, unpolymerized carbon monosulphide seems to

be produced, and this possesses the remarkable property of spontaneously polymerizing at a slightly higher temperature with explosive violence and forming a brown powder.—*Chem. News*, cii, 49 and 61. H. L. W.

2. *The Action of Carbon-Tetrachloride upon heated Anhydrides, Oxides, and several Minerals.*—This method of simultaneously reducing oxides and forming chlorides has been the subject of many investigations for more than twenty years. CAMBOULIVES, however, has recently studied the process systematically, using a large number of oxides. The substances were placed in a boat within a tube of Bohemian glass, heated by means of a combustion-furnace, and vapor of carbon tetrachloride was passed through the tube. The temperature at which the reaction commenced was found by the use of a Le Chatelier thermo-electric couple placed within the tube near the boat. Care was taken to use as far as possible substances of the same degree of pulverization, but it was impossible to obtain the same porosity in all cases. For instance, the alumina prepared by the ignition of ammonium alum was readily attacked, while natural corundum was acted upon slowly and incompletely.

It was found that the temperatures of reaction are usually low, varying from 215° C. (with niobic anhydride) to 580° C. (with chromic oxide). The product in almost all cases is a chloride, for among the thirty oxides that were attacked only the oxides of niobium and thorium gave oxychloride, which in both cases was mixed with chloride. The process is well suited not only for the formation, but for the practical preparation of many anhydrous chlorides, especially those of the rare earth metals, chromium, nickel, vanadium, titanium, zirconium, beryllium, cadmium and cobalt.

Two oxides, silica and boracic anhydride, were found to be unattacked by the operation under consideration, but certain silicates are attacked to a degree apparently inversely proportional to their richness in silica, and the hydrous silicates are completely transformed into chlorides. Hence a mixture of clay and sand may be analyzed in this way, since the silicate of alumina forms the volatile chlorides of silicon and aluminium, and the sand is left behind.—*Bulletin*, IV, vii, 616. H. L. W.

3. *A New Method for Separating Tin and Antimony.*—In connection with an investigation in which a number of acid fluorides were prepared, FISCHER and THIELE have observed that antimonious and stannous acid fluorides are different in their behavior with hydrogen sulphide. A solution containing tin and antimony is first oxidized, so that the metals are in the stannous and antimonious conditions; then the sulphides are precipitated with hydrogen sulphide and dissolved in hydrofluoric acid. In this solution hydrogen sulphide precipitates reddish brown antimonious sulphide, leaving the tin in solution. By evaporating this solution in a platinum dish with sulphuric acid until the hydrofluoric acid has been expelled, and taking up the residue with water,

a solution is obtained from which the tin may be precipitated with hydrogen sulphide. It does not appear that the method has been tested by quantitative experiments, but the results are interesting in indicating the possible interference of hydrofluoric acid in analytical operations where tin is present.—*Zeitschr. anorgan. Chem.*, lxvii, 315.

H. L. W.

4. *Manufacture of Ethyl Alcohol from Sawdust.*—It is stated that ethyl alcohol—not methyl, or wood alcohol—is being made from sawdust on a large scale in France, and that the process will soon be put into operation in the United States and Canada. The process was invented by Dr. ALEXANDER CLASSEN of Aachen, Germany, and consists in heating the sawdust under pressure with water and sulphurous acid, thus converting the cellulose into fermentable sugar. The sulphurous acid is then drawn off, a certain amount of acetic acid formed at the same time is distilled off and saved, and the liquor separated from the residue is neutralized, fermented, and distilled. It is claimed that the insoluble residue of the process may be used as food for stock, and that 30 gallons of alcohol may be made from a ton of sawdust.—*Chem. News.*, cii, 41.

H. L. W.

II. GEOLOGY AND NATURAL HISTORY.

1. *The California Earthquake of April 18, 1906. Report of the State Earthquake Investigation Commission. Volume II. The Mechanics of the Earthquake*; by HARRY FIELDING REID. Pp. viii, 192; with 2 plates and 62 figures. Washington, D. C., 1910. Published by the Carnegie Institution.—This second volume of the report of the California Earthquake is of great scientific interest.* It consists of a first part on the phenomena of the megaseismic region, a second part on the instrumental records of the earthquake, and an appendix on the theory of the seismograph. The purpose of the review will be to give a summary of some of the conclusions of general interest contained in the first two parts.

In discussing the permanent crustal displacements resulting from the earthquake, it is noted that the shifting at the San Andreas fault line amounted to about 6 meters, the southwestern side moving northwest. The geodetic surveys carried on from 1874–1892 and in 1906–1907 showed that the Farallon Islands, 37 kilometers southwest of the fault, had moved northward 1·8 meters. The movement of the latter Reid does not regard as accomplished at the time of the shock, but as going forward gradually and accompanying the accumulation of the stresses which were finally relieved at the time of fracture. That is, two-thirds of the stress which caused the rupture had already accumulated 25 years ago, and 50 years ago, as shown by the surveys of

* See G. K. Gilbert, this Journal, xxvii, 48.

1851-1865, the elastic strain, which caused the rupture in 1906, had already accumulated to nearly half its final amount. It seems not improbable, therefore, that the strain was accumulating for one hundred years.

The distribution of the distortion of the rock resulting from the earthquake shows that the previous strain was highly concentrated within a few kilometers of the fault line. The strain per unit area must rise to a certain value before fracture results. If the strain had extended over a wider zone, a greater displacement would have occurred at the time of fracture. Since, however, the throw of six meters is a large one for an earthquake, it seems conclusive that in fault movements in general the preceding strain between the adjacent crust blocks is confined to a relatively narrow zone.

Reid next considers the possibility of the prediction of earthquakes by measuring the growing strains in a fault zone. For this purpose a line of piers should be built, say a kilometer apart, at right angles to the direction of the fault line. Starting from a time when the zone is comparatively free from strain, as is to a large extent true in the San Andreas rift at the present time, geodetic measurements at intervals of some years would determine the amount of growing distortion in this line at right angles to the fault. When the surface becomes strained through an angle of about $1/2000$ we should expect a strong shock to relieve this strain. It seems probable that a very long period will elapse before another important earthquake occurs along that part of the San Andreas rift which broke in 1906; for we have seen that the strains causing the slip were probably accumulating for one hundred years. It is quite possible, however, for strong earthquakes to occur on neighboring faults after short intervals. The ruptures of the Haywards fault in 1868 and of the San Andreas fault in 1906 are fair examples, though the interval is rather long. The Haywards fault passes through Berkeley, and is 30 kilometers northeast of the San Andreas fault.

The second part of this volume deals with the instrumental records of the earthquake. On account of the great energy of this earthquake it was recorded by seismographs in all parts of the world, and these seismograms supply a large amount of data. The first topic considered is that of the increasing duration of the disturbance as the distance of the station from the origin is greater. The major reason for this is that the longitudinal waves travel faster through the earth than do the transverse waves, but Reid suggests in addition the analogy of a clap of thunder, which although a sudden crash at its point of origin is heard at a distance as a prolonged reverberation. Reflections of the elastic waves from the many surfaces in the outer zone of the crust serve to prolong and mix the vibrations, but with each reflection a partial transformation of the wave motions is produced, a wave motion of a single character being reflected as partly longitudinal, partly transverse vibrations. Consequently the waves become

mixed in nature as well as in duration. Such mixing is, however, doubtless a phenomenon attending the passage of the waves through the outer shell of the crust only, so that clear distinctions between the first and second preliminary tremors and the main waves are not lost. Plotting of the times of beginning of the first and second preliminary tremors and of the principal part indicate clearly that the first two are transmitted through the earth, the latter around the earth. As the times of transmission through the earth are dependent upon the changes in the nature of the centrosphere dependent upon depth the preliminary tremors are of great interest. Unfortunately at distances greater than 100° for the first preliminary tremors and 125° for the second preliminary tremors, the observations of the phases become extremely doubtful. This further emphasizes the importance of installing instruments recording the vertical component of motion, and instruments with high magnifying powers, not less than 100.

Following Wiechert's method, the curves representing the normals to the wave fronts and the velocities at various depths are computed from the data of the seismograms. As shown in fig. 28 of the report, the velocity of the longitudinal waves increased rapidly with depth, but with decreasing rapidity, from 7.2^{km} per sec. at the surface to 12.5^{km} per sec. at 2170^{km} from the surface, $.66$ of the radius from the center. Below that depth the velocity is nearly constant. The velocity of the transverse waves is 4.8^{km} per sec. at the surface and increases almost linearly with depth, reaching a velocity of about 7.5^{km} per sec. at half the distance to the center of the earth. The absence of good records from distances beyond 125° prevents a knowledge of the velocities at greater depths. Within the limits regarding which information is given, Reid remarks that there is no indication of a sudden change in the velocity of either wave such as we should expect if there were any sudden changes in the nature of the earth's interior.

In discussing the surface waves the most important point is to determine the time when they begin. This is chosen by Reid where the irregular movements due to the second preliminary tremors give place to regular waves with a long period (30 to 50 seconds). The velocity of transmission is uniform along the great arcs of the earth and the seismograms of the San Francisco earthquake give 88 minutes as the time to reach the antipodes. No variations in velocity along different paths are to be detected greater than the errors of observation. Thus the velocity under the Pacific ocean to Japan is the same as under North America and the Atlantic ocean to Europe.

On comparing these results with those of Milne in 1902 and Oldham in 1900 it is seen that the preliminary tremors are for the greater part of the curve about 2 minutes earlier, apparently from lack of accuracy in the earlier observations. Determinations of velocities given by different great earthquakes are shown

to be of great supplemental value, since the best seismographs give records which are in consequence at different distances from the origin.

In regard to periods and amplitudes: many periods are present during the first and second preliminary tremors and the instruments single out and make prominent those which are near the period of the instrument. The periods of the first tremors are mostly limited to a quarter of a minute, of the second tremors mostly between a quarter and a half of a minute. The amplitudes of the first tremors range about one-tenth those of the second. They are measured on the average by tenths and hundredths of a millimeter respectively at distances between 20° and 100° from the origin. The periods of vibration of the regular waves were in general not very far from 30 seconds. In the megaseismic region the amplitudes were 50^{mm} or more; at distances of 30° to 50° they have diminished to about 5^{mm} , and we must go as far as 100° or so to find amplitudes less than 1^{mm} . We see, therefore, that the great world-shaking earthquakes cause movements of the earth at great distances which are by no means inconsiderable, and the only reason why they are not felt is that the period, and, therefore, the movement is too slow to make them evident to our senses. In conclusion, Reid points out the importance of damped instruments, of a high magnifying power and an open time scale. It is from instruments possessing these qualities that future increases in this branch of knowledge are to be expected.

The third part, on the theory of the seismograph, although of great importance is of more particular interest to specialists in earthquake phenomena.

J. B.

2. *West Virginia Geological Survey. County Reports and Maps. Pleasants, Wood, and Ritchie Counties*; by G. P. GRIMSLEY. Pp. xiv, 352, with 21 plates, 16 figures, and 3 maps in atlas. Also, *Map of West Virginia* (as a separate publication), scale 7 miles to the inch, showing coal, oil, gas, and limestone areas, by I. C. WHITE. Morgantown, West Virginia, 1910.—This report by Professor Grimsley gives very complete information regarding the three counties named and is of practical as well as scientific value. The chief resources of the region lie in its soils derived from the Permian shales and sandstones and in the abundant accumulations of petroleum.

J. B.

3. *Supplementary Investigation in 1909 of the Figure of the Earth and Isostasy*; by JOHN F. HAYFORD, Inspector of Geodetic Work, and Chief, Computing Division, Coast and Geodetic Survey. Pp. 80, 5 maps in pocket. Washington, 1910.—The noteworthy contribution by this author on "*the Figure of the Earth and Isostasy*" has been reviewed in the number of this Journal for February, 1910. The first paper embraced the results of observations up to 1906. In this supplement, the results are confirmed and made more accurate, embracing observations up to 1909 and including some improvements in method. The number of astronomical determinations employed in the first

computation was 507, in the second it was 765, including those of the first. The final values of the equatorial radius of the earth compared to previous determinations are as follows:

Clark, 1866	6,378·206	meters
C. and G. Survey, 1906	6,378·283 ± 34	"
C. and G. Survey, 1909	6,378·389 ± 18	"

The values for the depth at which isostatic compensation becomes complete are eight per cent greater than in the determinations from the first paper. Some discussion and several charts are also given of areas of excessive and deficient density in the United States. The geologic importance of the geodetic study of these local departures from isostatic equilibrium is obvious, but the work has as yet hardly advanced to sufficient completeness to enable comprehensive conclusions on this subject to be drawn.

J. B.

4. *The Gold Hill Mining District of North Carolina*; by F. B. LANEY. Bull. No. 21, North Carolina Geol. and Econ. Surv. Pp. 119, 23 plates, 5 figs.—The Gold Hill Mining District lies in the south-central portion of the state in Rowan, Cabarrus and Stanley counties. The principal surface features are a long, low-lying, flat-topped ridge, the Gold Hill Ridge and a series of hills, the Beaver Hills. The rocks of the district are about equally divided between the sedimentary and igneous groups. The sedimentary series, consisting of slates, tuffs and breccias, intercalated with which are minor flows of rhyolite and andesite, makes up its southeastern portion. The igneous rocks, which lie in the northwestern half, consist chiefly of a much metamorphosed basic effusive rock, called a greenstone, into which diorite and granite have been intruded. These two rock series are separated from each other by a great fault, the Gold Hill fault, which extends across the district in a northeast direction. This fault is marked by a zone of highly crushed and schistose rocks, much minor and local faulting and numerous closely spaced joints. There is much folding of the sedimentary rocks, particularly near their contact with the igneous area.

The ore-bearing veins are developed in the zone of minor faulting to the east of the Gold Hill fault. They appear for the most part to follow the trend of the fault, but are often found following the strike of the schistosity. They are of two types, one of which is marked by an extensive silicification of the wall rock and is largely gold-bearing with only small amounts of copper. The other presents a minimum of silicification and consists of a zone of narrow rifts in the slate parallel with the schistosity. This series carries chiefly copper with only small amounts of gold. The ores are chiefly auriferous pyrite and chalcopyrite. In general the pyrite is the older mineral, and after deposition was more or less shattered by further movements. This shattering was followed on the one hand by the deposition of chalcopyrite and more pyrite, and on the other by the introduction of pyrite and gold,

the auriferous pyrite. It is believed that the two series of veins represent two distinct periods of mineralization or possibly two sources for the ore-bearing solutions. W. E. F.

5. *University of Illinois Bulletin*. Vol. 7, No. 2. September 13, 1909. Chemical and Biological Survey of the Waters of Illinois: Report for year ending December 31, 1908. EDWARD BARTOW, Director. Pp. 204. Water Survey Series, No. 7. Urbana, Illinois.—This bulletin is of much local importance, containing as it does an examination of many thousand samples of water from different sources. It is noted that up to the close of 1908 the State Water Survey received 18,700 samples of water for examination. Not only the results of analyses themselves are given, but also several chapters dealing with general topics, as the determination of nitrates in drinking water, the methods of water analysis, etc.

6. *The New Bureau of Mines of the United States Geological Survey*.—The Bureau of Mines, recently established as a part of the U. S. Geological Survey, began its work with the first of July. This Bureau will have charge of the investigation of mine accidents and fuels, together with the personnel and equipment of these investigations; it also embraces the fully-equipped testing station at Pittsburg. The related investigations of the structural materials will be carried on by the Bureau of Standards. An appropriation of \$310,000 has been made by Congress for the investigations of mine accidents, and \$100,000 for the analysis and testing of the various fuels; the total appropriations for the Bureau of Mines, including salaries, rent, etc., amount to \$502,200.

It is stated that "the work of the Bureau of Mines for the first year will be a continuation and expansion of the work carried on by the Technologic Branch of the Geological Survey. The law in itself provides for a variety of other problems that properly belong to the Bureau of Mines and which should eventually be undertaken, such as methods of mining and metallurgical processes, but these activities will be deferred for the most part until Congress gives additional authorization in the shape of adequate appropriations. The spirit of the debates in Congress, both on the Bureau of Mines legislation and on the appropriation items, emphasized the desire to regard the mine accidents investigations as urgent, and this will be the feature of the work."

The mine accidents investigations, begun by the Geological Survey in 1908, have already accomplished important results. Since 1908 "investigations of explosives, coal, gas, dust, electricity, and other possible causes of mine explosions have been continually under way. The mining engineering field force of the Geological Survey has already made decided progress in the study of underground mining conditions and methods. Practically all of the coal mines in which mine explosions have occurred during the last two years have been carefully examined, the gases, coke and dust have been analyzed at the laboratory at Pittsburg and every effort has been made to determine the explosibility of vari-

ous mixtures of gas and air in the presence of shots of different types of explosives. Considerable progress has also been made in the investigation of explosives used in coal mining, and the conditions under which they may be used with least risk. Manufacturers have submitted many explosives for test at the station, and a considerable portion of them passed and have been classified among the permissible explosives. The investigations and educational work in connection with the use of artificial breathing and other types of mine rescue equipment, the so-called oxygen helmets, have not only been useful in developing a more satisfactory use of such equipment in the examination of mine explosions, but also better methods for using this equipment in mine rescue work."

The publications of the Survey relating to mine and fuel investigations, those prepared by the Technologic Branch, will in the future be distributed by the Bureau of Mines, but the publications relating to structural materials will continue to be distributed by the Geological Survey. The last of the bulletins of the Technologic Branch to be published by the Survey relates to the Explosibility of Coal Dust, and was prepared by G. S. Rice, with chapters by J. C. Frazer, Axel Larsen, Frank Haas, and Carl Scholz. The titles are given of a series of bulletins to be issued by the Bureau of Mines in the near future.

7. *The Evolution and Function of Living Purposive Matter*; by N. C. MACNAMARA. Pp. xi, 298. New York, 1910 (D. Appleton & Company: The International Scientific Series).—The book consists of two distinct parts, the first 187 pages containing a discussion of the evidence leading to the conclusion that the psychic nervous substance of the brain of the higher animals has been derived by a process of evolution from matter in the simpler organisms possessing only instinctive functions. An attempt is made to trace this gradual development of the purposive elements of the protoplasm in the most lowly forms of life into the specialized substance of the cerebrum of the human being. The nature of protoplasm and its relation to the hereditary qualities of the individual are discussed at length.

In the second portion there is given a remarkable illustration of the importance of heredity in determining individual character. This is shown by the history of the Celtic people, who lived in a nearly constant environment for 1200 years from the time of their settlement in Ireland about the year 450. The destinies of the individuals and of the race are shown to have been correlated with the inheritance of personal characteristics through successive generations.

W. R. C.

8. *Discussion on the Origin of Vertebrates*; by W. H. GASKELL, E. W. MACBRIDE, E. H. STARLING, E. S. GOODRICH, H. GADOW, A. SMITH WOODWARD, ARTHUR DENDY, E. RAY LANKESTER, P. CHALMERS MITCHELL, J. STANLEY GARDINER, T. R. R. STEBBING, and D. H. SCOTT. Reprinted from the *Proceedings of the Linnean Society of London*, pp. 9-50, 1910.—Two successive

meetings of the Linnean Society of London, on January 20 and February 3, of the present year, were devoted to the discussion of this topic. Dr. Gaskell first presented his much criticized theory maintaining an origin from an arthropod ancestor. In reply Prof. MacBride stated his objections to Gaskell's theory and supported the well-known hypothesis of the *Balanoglossus-Amphioxus* route of development. The further discussion consisted largely of objections to the one theory or the other, but in the main Gaskell's hypothesis was held to be founded rather on superficial resemblances than on ancestral relationships. Although the problem was as far from solution at the end of the two meetings as at the beginning, the published discussion affords the best criticism of the theories involved that has yet appeared, the subject having been briefly reviewed from the standpoint of the anatomist, physiologist, embryologist, paleontologist, and botanist.

W. R. C.

9. *The Vegetable Proteins*; by THOMAS B. OSBORNE. Pp. xxiii, 125. New York and London, 1909 (Longmans, Green & Co.).—In this little volume, which forms one of a series of monographs on biochemistry, edited by R. H. Aders Plimmer and F. G. Hopkins, the author confines himself to a discussion of the general and physical properties of the vegetable proteins. All students of chemistry will welcome this opportunity of securing from the pen of a recognized authority a simple and readable presentation of what has thus far been learned of one of the most difficult branches of the subject.

W. R. C.

10. *The Science and Philosophy of the Organism* (Gifford Lectures); by HANS DRIESCH. Volume II. Pp. xvi, 381. London, 1908 (Adam and Charles Black).—In the first volume of this important work on philosophical biology the chief results of analytical biology were discussed in their bearing on morphogenesis, adaptation, inheritance, systematics, and history. This discussion is concluded in the first 124 pages of the present volume, in which the nature of organic movements is considered. The second section of the work, entitled "The Philosophy of the Organism," discusses the philosophy of nature in general, the characteristics of entelechy, entelechy and univocal determination, entelechy and causality, entelechy and substance, the direct proof of the autonomy of life based upon introspective analysis of complete givenness, individuality, the problem of universal teleology, and metaphysical conclusions.

W. R. C.

III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *British Association for the Advancement of Science*.—The annual meeting of the British Association was held at Sheffield during the first week of September; some 1400 members were in attendance. The inaugural address, delivered by the President, Prof. T. G. Bonney, was devoted to an interesting discussion of "Some aspects of the glacial history of Western Europe." The

meeting of next year will be held at Portsmouth with Sir William Ramsay as president, and Dundee has been appointed as the place of meeting in 1912. In 1914 the Association will meet in Australia.

2. *Carnegie Institution of Washington*.—Recent publications of the Carnegie Institution are noted in the following list (continued from p. 94).

No. 53. *Egyptological Researches*. Vol. II. Results of a Journey in 1906; by W. MAX MÜLLER. Pp. v, 188, 47 plates.

No. 109. *Medusæ of the World*; by ALFRED GOLDSBOROUGH MAYER. Vol. I. The Hydromedusæ. Pp. 230, xv; 29 plates, 119 figures. Vol. II. The Hydromedusæ. Pp. 231-498, xv; figures 120-327, plates 30-55. Vol. III. The Scyphomedusæ. Pp. iv, 499-735; figures 328-428, plates 56-76.

No. 122. *Determinate Evolution in the Color Pattern of the Lady-Beetles*; by ROSWELL H. JOHNSON. Pp. iv, 104, 92 figures.

No. 124. *List of Documents in Spanish Archives relating to the History of the United States, which have been printed or of which transcripts are preserved in American Libraries*; by JAMES ALEXANDER ROBERTSON. Pp. xv, 368.

No. 126. *The Metabolism and Energy Transformations of Healthy Man During Rest*; by FRANCIS G. BENEDICT and THORNE M. CARPENTER. Pp. viii, 255.

No. 129. *The Conditions of Parasitism in Plants*; by D. T. MACDOUGAL and W. A. CANNON. Pp. iii, 60, 2 figures, 10 plates.

3. *Les Theories Modernes du Soleil*; par J. BOSLER, Astronome a l'Observatoire de Meudon. Pp. 382. Paris (Encyclopédie Scientifique, Octave Doin).—This volume deserves notice not merely for its individual excellence, great as that is, but still more because of its place in the series of volumes constituting the Encyclopédie Scientifique, which has already been noticed in this Journal in connection with another volume in the same subdivision of this great enterprise.

This is a handy volume Encyclopedia in numbers of pocket size aggregating eventually some 1000 volumes classified in 40 divisions or libraries, each library in charge of a specialist and comprising 20 to 30 volumes.

The number under review is the third of the set of 27 belonging to the library of Astronomy and Celestial Physics and is compiled by Bosler, astronomer of the observatory of Meudon, among the foremost of observatories in solar research since photography and the spectroscope have been available to unveil solar mysteries.

The work is as judicious and authoritative as its source would lead us to expect, and is written with the clearness and precision for which French scientists are preëminent.

The subdivision of this encyclopedia into 1000 volumes is with a view to continual revision as the progress of science requires, nowhere more necessary than in the science of solar physics, constructed as it is from the residuum of numberless evanescent guesses.

W. B.

4. *Celestial Ejectamenta*; by HENRY WILDE, D.Sc., D.C.L., F.R.S. Pp. 34 with 4 plates. (The first Halley Lecture at the University of Oxford.)—The lecture consists mainly of a number of novel propositions, for the most part stated without adducing proofs other than references to lectures or pamphlets of the author bearing on them. Most noticeable of these are the following:

Simplification of the theory advanced by Halley that terrestrial magnetism is due to rotation of the earth's interior (presumably plastic) relative to the surface, with a differential (synodic?) period of 960 years (Halley, 700 years).

That periodic comets are planetary "ejectamenta" (i. e. volcanic products of the plastic period). The "Capture Theory" is ignored, and the reality of hyperbolic orbits denied.

That the "red spot" of Jupiter is a volcano, whose "ejectamenta" produce the Jovian belts in the form of fine dust like that ejected by Krakatoa.

That Bode's Law and a kindred but more accurate one, not here stated, discovered by the author and based on Mercury's heliocentric distance as the unit, are examples of a "law of binary progression" to which the series of atomic weights also conforms. The author asserts that this "law of binary progression" is one of the fundamental laws of nature, and that it admits of only a teleological explanation, and is an evidence stronger than any other known to science of a causal intelligence guiding the universe.

The deviation of Neptune from the place required by Bode's Law is explained as due to its perturbations by the inner planets, which perturbations, it is asserted, are cumulative rather than compensating, and will, therefore, eventually precipitate the planet upon Uranus. This, it is needless to point out, destroys the gravitational stability of the solar system and charges Laplace and Lagrange with folly. We agree with the lecturer that "it is not a little remarkable that the effect . . . never presented itself to writers on celestial mechanics who have elaborated the doctrine of the absolute stability of the solar system." W. B.

5. *Elementary Dynamics for Students of Engineering*; by ERVIN S. FERRY, Professor of Physics in Purdue University. Pp. 182. New York, 1910 (The Macmillan Company).—An excellent text-book for all college students preparatory to Physics as well as for those in Engineering, whether in connection with the Calculus or not. The methods are rigid without unnecessary refinement, the applications are numerous, fresh and pertinent, and the underlying principles of the science are presented distinctly by themselves and in a manner to show that they are not, as they are often made to appear to beginners, abstractions but generalizations from experience. W. B.

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ART. XXXII.—*Pleistocene Glaciation and the Coral Reef Problem*; by REGINALD A. DALY.

Introduction.—During the last thirty years, most of the active students of atolls and barrier reefs have tended to oppose the Darwin-Dana hypothesis of extensive and prolonged crustal subsidence in the Pacific and Indian ocean basins. The borings at Funafuti do not seem to have proved the hypothesis even in the case of this one atoll. In Hinde's detailed description of the cores we read that, from the top down to the 150-foot level their material is chiefly coral. Of the remainder of the boring, 663 feet are noted as principally composed of detrital and foraminiferal matter; 279 feet carry small masses of coral, but the relative proportion of coral rock, as opposed to detrital and foraminiferal matter (here also abundant), is not stated; while only 22 feet, in all, of the core below the 150-foot level is described as originally solid coral rock.* These figures and, yet more clearly, the thoroughly particularized text of the report, suggest that the 1,114-foot boring penetrated—first, a true reef extending little deeper than the bathymetric limit of reef-building corals; and then, a much thicker talus deposit containing blocks of massive coral. At several of the deeper levels the corals found are stated to have been "probably in the position of growth," but no discussion of this principal conclusion is contained in the report. Though most of the material constituting a typical reef is not solid coral rock, the percentage of non-detrital coral rock in the Funafuti main boring appears to be much too low to prove the Darwin-Dana hypothesis.

On the other hand, Semper, Murray, Alexander Agassiz, and others have long contended that coral reefs have been formed

* See Section xi of report on "The Atoll of Funafuti," London, 1904.

either in areas of elevation or in areas of long-continued crustal repose; though Agassiz accounts for the depth of certain lagoons and channels through local, very moderate subsidence.

In the literature of coral reefs there is no systematic discussion of another possibility which must fundamentally affect the theory of coral reefs; namely, a positive movement of sea-level in the coral-reef zone of the earth, independently of crustal subsidence. The writings of Suess have now made this idea very familiar, and few geologists will be disposed to deny the validity of the principle. In the following pages the attempt is made to show that the melting of the Pleistocene glaciers in both northern and southern hemispheres resulted in a slow, relatively small, but theoretically important raising of sea-level throughout the intertropical zone. Most of the plateaus from which annular and barrier reefs rise are credited to Pleistocene marine erosion operating on Tertiary islands, shoals, or continental shores. The corals colonized those plateaus during late Pleistocene time and have since continued the reef growth. The atoll and barrier-reef forms were inevitable consequences of the late Pleistocene drowning.

This conception thus seems to supply a missing link in the chain of argument used by Semper, Rein, Murray, Agassiz, and Guppy against the wholesale-subsidence hypothesis. Darwin and Dana depended very largely on the visible forms of coral reefs in constructing their ingenious theory. If it can be shown that these forms were produced by increase of ocean water in the equatorial zone, the hypothesis of enormous crustal deformation beneath the coral archipelagoes is shorn of its strongest argument.

In one instance the writer has been successful in the search for earlier statements of the relations between Pleistocene glaciation and the forms of coral reefs. After describing evidences of the recent drowning of most islands and coasts, Penck writes: "The causes of the general rise of sea-level in the latest geological time might perhaps be connected with those climatic changes which the earth underwent in the Glacial period. If, during that time, northern Europe, northern North America, and the Antarctic regions were simultaneously glaciated, a considerable mass of water must have been removed from the ocean, and, if the thickness of ice be assumed as 1,000 meters, the sea-level must have been 150 meters below its present position."* The context of this passage gives no explanation of the flatness and nearly uniform depth of the plateaus on which the visible reefs have been built. Partly for this reason, Penck's suggestion has not received, in the recent writings on coral reefs, the attention it deserves. In any case, it is

* A. Penck, *Morphologie der Erdoberflaeche*, vol. ii, 1894, p. 660.

time for renewed emphasis on the vital connection between Pleistocene glaciation and the conditions of Pleistocene inter-tropical seas.

Effect of Pleistocene glaciation on intertropical sea-level.—It is becoming increasingly apparent that the southern hemisphere was affected by Quaternary glaciation contemporaneously with the northern hemisphere.* At the time of their maximum extension the ice-sheets, which have since melted away, covered a total area which may be estimated as from five to eight millions of square miles. One will not go far astray in assuming six millions of square miles as the area thus deglaciated on the earth as a whole. This is one twenty-fourth of the present area of the ocean.

The average thickness of the ice cannot yet be determined, but its order of magnitude can be stated. The depth and surface gradient of the Labrador ice-cap were sufficient to drive that sheet over the mountains of New England and New York state, and to give the effluent ice-streams crossing the Torngat mountains of northeastern Labrador thicknesses of more than half a mile.† The writer has found the maximum thickness of the Cordilleran ice-cap of North America at the 49th parallel of latitude—near the southern limit of the cap—to be over 6,000 feet, and the average thickness about 2,500 feet. The ice-cap of northwestern Europe varied between 1,500 feet in thickness at the Harz mountains to “perhaps between 6,000 and 7,000 feet” in thickness over Scandinavia, and “the sheet may have been as much as 4,000 or 5,000 feet thick in the northern part of Britain.”‡ Penck has estimated that the average thickness of the Pleistocene ice was well over 1,000 meters.§

The removal of enough water to form these great sheets of ice would tend to lower sea-level all around the globe by the amounts here approximately stated :

<i>Estimated average thickness of ice</i>				
(in feet) -----	3,000	3,600	4,000	5,000
<i>Corresponding decrease of ocean's</i>				
<i>depth (in feet) -----</i>	125	150	167	208

Woodward, Hergesell, and others have shown that a second cause for a negative movement of sea-level in the equatorial zone is to be found in the gravitative power of the ice. Using Woodward's formulas, it may be calculated that, if the ice had an area of 6,000,000 square miles and an average thickness

* Cf. H. Hess, *Die Gletscher*, Braunschweig, 1904, p. 396.

† See Bulletin, Museum of Comparative Zoölogy at Harvard College, vol. xxxviii, p. 251, 1902.

‡ Sir Archibald Geikie, *Textbook of Geology*, vol. ii, p. 1305, 1903.

§ A. Penck, *Separatabdruck*, *Jahrbuch Geog. Gesell. zu München*, vii, p. 30, 1882.

varying from 3,000 to 5,000 feet, the attraction of the ice would lower the level of the equatorial sea by amounts ranging from five to eight fathoms.*

Taking the two effects together, the formation of the ice-sheets (which have since disappeared) would produce a negative movement of sea-level in low latitudes to an amount ranging between twenty-five and forty-five fathoms. Assuming 3,600 feet as the average thickness of the ice, the shift of level in the equatorial sea would be about thirty fathoms.† Conversely, the deglaciation of the full 6,000,000 square miles would raise the level in the equatorial zone by about thirty fathoms.

The Plateaus.—Can we connect the later, positive, movement of level with the forms of existing annular and barrier reefs? That question suggests another, as to the origin of the broad plateaus on which the reefs have been built.

A principal datum for the discussion of this subject must be the range of depths of the water above the plateaus. An approximation to those depths is given in the depths of the atoll lagoons and of the barrier channels. It is clear, however, in spite of Murray's hypothesis of solution as explanatory of lagoons, that the vast majority of lagoons and barrier channels are slowly filling up; so that the average depth of the plateau is somewhat greater than the average depth of the deeper part of lagoon or channel.‡ In the case of many a small atoll, which, on account of limited size, has been nearly filled with calcareous deposits, the plateau is many fathoms below the deepest hole in the lagoon.

The following table (col. 1) gives the maximum depths of water charted in representative atoll lagoons and barrier channels of the Pacific and Indian oceans.§ In some cases the depths are given for great plateaus bearing relatively few reefs. These depths are usually greater than the maximum depths in atoll lagoons and barrier channels, but are of the same order of magnitude. Column 2 shows the estimated average depths of the deeper and generally considerable parts of lagoons or channels.

* R. S. Woodward, Bull. U. S. Geol. Survey, No. 48, 1888, pp. 41, 70, etc.

† Penck's estimate of 150 meters for this change of level seems too high, even if the volumes of the present Antarctic and Greenland ice-caps be included in the computation.

‡ Cf. W. J. Sollas, in "The Atoll of Funafuti," 1904, pp. 6 and 27; and R. Langenbeck, *Die Theorien über die Entstehung der Koralleninseln*, Leipzig, 1890, p. 50 ff.

§ Nearly all figures in this table have been derived from Agassiz's very convenient reproductions of Admiralty and other charts, to be found in *Bulletins* Nos. 28 and 33, and *Memoirs* Nos. 28 and 29, of the Museum of Comparative Zoology at Harvard College (1898-1903).

	1	2	3	4	5
	Max. depth (fathoms).	Mean depth in deeper part (fms.).	Extreme width (miles).	Extreme length (miles).	Exposure to waves (quadrants).
Great Barrier, Australia					
10-12° S. Latitude -----	32	15	72	--	2
12-14 " -----	27	15	35	--	2
14-16 " -----	34	20	33	--	2
16-18 " -----	37	20	35	--	2
18-20 " -----	36	22	65	--	2
20-22 " -----	37	25	100	--	2
Fiji Group					
Viti Levu, N. W. coast, barrier	46	35	30	--	2
" " E. " " "	42	22	15	--	2
Vanua Levu, S.W. " " "	49	35	15	--	2
" " N. " " "	46	35	25	--	2
Wakaya, barrier -----	35	30	4	--	2
Mbengha, " -----	32	20	12	12	3
North Astrolabe Reef, barrier	18	10	3	4	4
Great " " " "	31	20	6	10	3
Ngau, barrier -----	26	25	4	--	2
Nairai, " -----	26	18	3	5	3
Ringgold islands, atoll -----	52	40	6	30	4
Exploring islands, barrier -----	101*	40	10	25	3
Reid reef, atoll -----	20	18	6	7	4
Southern Argo reef, atoll -----	36	30	5	9	4
Hao, atoll (Paumotu group) -----	31	30	10	35	4
Gambier islands, barrier -----	38	18	6	7	2
Society Islands					
Tabiti, E. coast, barrier -----	31	20	1.5	--	2
" " Taiaropu, " -----	30	25	1.5	--	2
Tahaa, barrier -----	27	20	2	--	2
Raiatea, " -----	33	20	2	--	2
Murea, " -----	27	20	1.5	--	2
Bora Bora, " -----	25	18	2	--	2
Huaheine, " -----	28	20	1.5	--	2
Tonga Group					
Nomuka group, plateau -----	ca. 48	40	20	25	4
Haapai " " (S. pt.) -----	ca. 50	40	16	25	4
Vavau " " -----	ca. 65	55	12	25	4
Vavau island, barrier -----	50	40	---	--	-
Funafuti, atoll (Ellice group) ---	30	25	9	14	4
Arhno, atoll (Marshall islands) --	32	22	10	20	4
Truk islands, barrier (Carolines)	36	30	35	35	4
Maldivé Group					
Ihavandiffulu, composite atoll ---	34	30	6	12	4
Tiladummati, " " -----	29	20	12	30	4
Miladummadulu, " " -----	32	28	18	54	4
N. Molosmadulu, " " -----	31	24	---	--	-
Middle " " " -----	26	20	20	60	4
South " " " -----	36	30	---	--	-
Fadiffolu, " " -----	32	28	18	24	4
North Male, " " -----	38	33	20	24	4
South Male, " " -----	37	30	10	20	4
Felidu, " " -----	40	35	14	28	4
Ari, " " -----	43	35	15	48	4
North Nilandu, " " -----	37	30	14	18	4
South " " " -----	39	30	12	20	4

* At a local, very narrow trough in the lagoon.

	1	2	3	4	5
	Max. depth (fathoms).	Mean depth in deeper part (fms.).	Extreme width (miles).	Extreme length (miles).	Exposure to waves (quadrants).
Mulaku, composite atoll.....	42	35	15	25	4
Kolumadulu, ".....	45	40	24	27	4
Suvadiva, ".....	48	40	33	50	4
Makunudu, atoll.....	17	10	6	18	4
Horsburgh, ".....	23	20	4	9	4
Gaha Faro, ".....	22	20	4	7	4
Rasdu, ".....	23	18	4	5	4
Wataru, ".....	21	18	3	4	4
Addu, ".....	36	30	7	10	4
Haddumati, ".....	42	38	13	20	4
Great Chagos Bank,.....	50	40	60	90	4

Columns 3 and 4 give the respective extreme widths and lengths (in geographical miles) of atoll-bearing plateaus, and the width of the plateaus surmounted by barrier-reefs. Column 5 states the approximate degree of exposure of each plateau to marine erosion; the coasts with barrier reefs being generally exposed to waves from two quadrants; and atoll-bearing plateaus generally so exposed in all four quadrants.

The average maximum depth of the lagoons and channels is about 35 fathoms. The average depth of the great plateaus which bear relatively small areas of reef-rock is about 45 fathoms. The difference between the two averages, or 10 fathoms, may nearly represent the average depth to which the lagoons have been filled by calcareous matter since the existing reefs began to grow. Removing from the plateaus their veneers of solid reef-rock, coral detritus, and the exuviae of algæ, foraminifera, etc., we should have something like 45 to 50 fathoms of water on each of these vast platforms. The relative uniformity of depth in each of the broader lagoons and the striking lack of strong variation in the depths of greater lagoons and barrier channels all around the world, would be at least matched by the uniformity of depths on the plateaus so uncapped.

In explanation of the smoothness of the plateaus and of their steady adherence to the average depth of about 45 fathoms, neither the Darwin-Dana hypothesis of prolonged subsistence nor the Murray hypothesis of solution is adequate. In his last volume Suess writes: "Notwithstanding the valuable investigations quite recently made, and notwithstanding the objections which such distinguished investigators as Semper, Murray, Agassiz, and so many others have raised to the views of Darwin and Dana, it must still be admitted that

the depth of the enclosed lagoon has not yet been completely explained. Thus, the view that the crown has been built up by corals during positive movement has still some foundation.”*

That the plateaus are due to erosion, coupled with the deposition of the eroded material as an advancing submarine talus, seems to be the preferable explanation. A full discussion of the point will not be made here, as it would demand many pages compiling the arguments of the older hypotheses and would thus unduly lengthen the present note. Suffice it to say, that in crediting the forms and hypsometry of the plateau surfaces essentially to marine abrasion, we make the only assumption which seems able to match all the facts.

It is not likely that the plateau surfaces were shaped when sea-level had its existing relation to the general sea bottom. Even the Pacific breakers cannot effectively erode the bed-rock of a broad shelf with depths approaching 45 fathoms. It is hard to believe that they could lower the plateau surfaces to such depth in any permissible time.

On the other hand, the conditions for the development of the platforms by marine abrasion were met during the Glacial period. For a large part of that epoch the level of the inter-tropical ocean was about 30 fathoms lower than now. Chamberlin and Salisbury have estimated that the length of the Glacial period was from 300,000 years to more than 1,000,000 years.† The entire time during which there was heavy glaciation, comparable to that of the maximum ice-caps, must have been much more than 100,000 years. The Pleistocene islands were subjected to the attack of waves and currents operating near a sea-level which shifted up and down with the maxima and minima of glaciation; but we may conceive that the net result was the preparation of broad benches and platforms at depths ranging from zero to fifteen or twenty fathoms below the last of the low Pleistocene sea-levels.

In a second principal way the Pleistocene conditions of abrasion in the equatorial ocean probably differed from those now ruling in the same latitudes. Some of the best authorities on the Glacial period hold that the whole surface of the earth was chilled during that time.‡ A fall of only half a dozen degrees in the average temperature of the intertropical seas would make an enormous difference in the distribution of the stenothermic reef-corals, which cannot withstand a

* E. Suess, *The Face of the Earth*, trans. by H. B. C. Sollas, vol. iv, 1909. p. 327.

† T. C. Chamberlin and R. D. Salisbury, *Geology*, vol. iii, 1906, p. 420.

‡ H. Hess, *Die Gletscher*, Braunschweig, 1904, p. 398; T. C. Chamberlin and R. D. Salisbury, *Geology*, vol. iii, p. 327, 1906; A. Penck, *Morphologie der Erdoberflaeche*, vol. ii, pp. 528, 660, 1894.

winter temperature below 20° C. The February marine isotherm of 20° lies but a few hundred miles north of the larger Hawaiian islands. We may be certain that those islands were not bordered by living reefs at a time when 4,000,000 square miles of ice capped the neighboring continent. Hawaii itself seems to have borne at least one small glacier, the characteristic traces of which were observed by the writer on Mauna Kea at the 12,000-foot level. The supposition that the present Hawaiian reefs began their growth in the post-Glacial interval is corroborated by the fact of their small size; they have evidently been growing but a short time.

The latter statement may also be made concerning the majority of the coral reefs of the globe.

Is it not fair to believe that the reef corals were confined, during the Glacial period, to very limited areas, where prolonged winter cold did not surpass 20° C.? The reef corals were, of course, not exterminated during the Pleistocene, but they may well have been restricted to such warm, more or less enclosed seas as those of the East Indian region.

The imagination suffers, therefore, no painful stretch in our considering that, throughout the Glacial period, extensive marine abrasion in the equatorial belt was possible because of a general lack of growing coral reefs in the open ocean. The undefended islands, largely composed of relatively weak volcanic and calcareous materials, must, under the conditions, yield extensively to the waves, which as a rule ran in from very deep water on every side and thus, with special power, attacked the islands.

All competent observers agree that most of the atoll-forming reefs are founded on denuded volcanoes. Judging by the analogies found in Hawaii, Samoa, Fiji, etc., a large proportion of these truncated volcanoes, in their subaerial portions, were composed of massive lavas as well as of very much weaker ash and tuff deposits. To reduce such masses, wave erosion would demand vastly more time than is represented in the Glacial period. But there is no reason to doubt that the volcanoes here considered are of many different ages, possibly from the pre-Cambrian to the Tertiary. For the older ones, subaerial denudation must have gone still further than it has in greatly dissected islands, like Kauai, Tahiti, etc., and thus approached or reached peneplanation of the islands. Such denudation, combined with marine erosion during pre-Pleistocene time, had reduced most of the volcanic masses to the plateau form. As the recently elevated islands so often show, many of these platforms became veneered with, and flanked by, Tertiary limestone, and doubtless they were often capped by coral reefs of much greater total area than that of the existing coral reefs.

The Pleistocene islands, emerging because of the negative movement of sea-level, were, therefore, generally low (under 300 feet* in height), and, above the new sea-level, were composed largely of weak material. Exposed on all sides to abrasion by the open ocean, we may safely assume that these islands would lose substance at least as fast as the 300-foot chalk cliffs of Dover, namely, at the average rate of 3 feet 6 inches a year. At that rate, the Chagos Bank, by far the most extensive of the plateaus here considered (sixty miles by ninety miles), could have been reduced to the Pleistocene sea-level in about 50,000 years. The whole duration of nearly maximum glaciation in the Pleistocene was, as we have seen, much longer than that. The estimate allows nothing for that fraction of the Chagos plateau which is due to off-shore deposition during the abrasion; but this process, complementary to the abrasion, obviously explains a notable part of each plateau area.

We may conclude that marine erosion, under Pleistocene conditions, was amply competent to reduce most of the Tertiary thalassic islands to a low Pleistocene sea-level (see cols. 3, 4, and 5 of table). The same is true of the Australian continental shelf and of the similar shelves of New Guinea, Fiji, etc. Though the Australian shelf reaches 100 miles in width and was exposed to erosion on only one side, a large part of it must have been composed of weak sediments; these were rapidly benched by the Pleistocene breakers.

On the other hand, the lava-formed islands of late-Tertiary or Pleistocene dates, like Hawaii, Tahiti, Savaii, Murea, Bora Bora, and Huaheine, would stoutly resist abrasion. Their benches are, accordingly, not more than about two miles in width.

Growth of the existing Reefs.—The melting of the huge ice-caps must have been a slow process. They began to dissipate, doubtless through a general amelioration of climate. We may believe that the new platforms were colonized by reef-building species quite early in the melting stage and before the rising sea-level meant water of more than twenty fathoms, that is, water too deep for most reef-building species. Though we do not know precisely the average rate of growth on coral reefs, we do know that it is, geologically speaking, very rapid. There would seem to be no difficulty in assuming the rate as quite sufficient to keep the living zones of the reefs well within the 20-fathom isobath of the deepening ocean. The mechanism of growth, with the resulting development of atoll, barrier, and fringing reef forms, would be analogous to that imagined by Darwin and Dana on the sub-

* This figure chosen on the assumption that the Antarctic and Greenland ice-caps were, perhaps, first formed in Quaternary time.

sidence hypothesis, though by the present writer's hypothesis most of the lagoons would tend to enlarge, rather than diminish in area, with the process of time.

Drowned Valleys of Oceanic Islands.—The Pleistocene deepening of the inter-tropical seas is precisely of the amount required to explain the drowned valleys of the volcanic islands which are now surrounded by barrier reefs. The following list is representative of the maximum depths recorded for the drowned portions of these valleys :

	Maximum depth charted in valley (fathoms)
Tahaa, Society Islands	22
Raiatea, " "	19
Murea, " "	26-41
Huaheine, " "	25
Vavau, Tonga archipelago (two valleys, each)	30
Mbengha, Fiji group	19
Moala, " "	16

The maximum depth charted for these drowned portions of the valleys appears never to exceed 45 fathoms.

Dana's contention that the drowned valleys indicate crustal subsidence evidently needs revision, since a recent swelling of the equatorial waters without crustal movement gives the same result. By the hypothesis here suggested, these valleys must have been deepened during the time of heavy glaciation, when their base-level was lower than now and that for a total time long enough for the deepening of each valley to the extent required by the hypothesis.

Composite Atolls of the Maldives.—Late Pleistocene drowning will account for the existence of the many small atolls or "faros"* which make up the emerged rims of the great atolls of the Maldivé archipelago. The typical form and relation of each "faro" to its main atoll fail of explanation on the Darwin-Dana hypothesis. Neither can the lagoon of the main atoll nor that of the bordering "faro" be explained by the doctrine of an unvarying sea-level. A study of the charts of the Maldives shows that Murray's hypothesis of solution by sea-water can hardly account for these lagoon basins. It may be recalled that, at Funafuti, the lagoon water is not sensibly richer in carbon dioxide (the special solvent invoked by Murray) than is the water of the open ocean; and, secondly, that the observers on Funafuti have decided that its lagoon is being slowly filled with shells, skeletons, and detritus, and is not increasing in depth through solution.

* Cf. A. Agassiz, *Memoirs Museum of Comp. Zoology at Harvard College*, vol. xxix, 1903, p. xii.

But, granting: (1) a very slow rise of sea-level during the late Pleistocene, (2) an early colonization of the Maldive platforms, and (3) lateral growth of a reef at a rate much faster than the drowning (a most probable assumption): we can imagine a late Pleistocene coral patch soon spreading "like a fairy ring" to the size and shape of a "faro" atoll. That the "faros" are concentrated on the edges of the platforms is a natural and well recognized effect of the conditions of coral growth.

Summary of Conclusions.—A statement of the view that most atolls and barrier reefs were formed during a period of relative crustal repose is not complete until the effect of the Pleistocene lowering and subsequent swelling of the equatorial waters is considered. Since the positive movement of sea-level was not general, being offset in higher latitudes by the annulment of glacial attraction, the effect in the intertropical seas may be described as a heaping or *tumular* movement of water above the antecedent geoidal surface. To that tumular movement the peculiar forms and relations of atolls and barrier reefs are directly attributed. This idea obviously in no sense excludes complications due to local warpings of the earth's crust, with, for example, negative movement of sea-level in Fiji and positive movement at the Great Chagos Bank. The changes in sea-level due to glaciation and subsequent deglaciation have been discussed as though other processes had not affected general sea-level. They have been so far neglected in the argument because of the high probability that neither basin-foundation, nor sedimentation, nor absorption of water by weathering rocks seem to have been important enough, since the Tertiary, to affect, by more than a fathom or two, the changes of level assumed.

The related view, that most of the great plateaus now bearing atolls and barrier reefs were finally truncated by Pleistocene marine erosion, explains the remarkable flatness of these platforms and their nearly uniform depth of 45 to 50 fathoms. As Suess points out, these features can hardly be explained, either on the Darwin-Dana hypothesis or on Murray's hypothesis of solution inside the reef. Murray's conception, that many of the plateaus have been built up by calcareous accumulations on volcanic peaks which, by eruptions, had reached to depths within a few hundred fathoms of the surface, is in ill adjustment with his solution hypothesis. In any case it cannot solve the problem for the vast majority of reef-bearing plateaus.

Since reef-building corals doubtless flourished in the equatorial seas during the Tertiary period, and there greatly protected island and mainland from wave attack, the develop-

ment of the smooth floors, on which the existing reefs stand, is not to be ascribed to Tertiary marine erosion. In fact, it is an open question whether the atoll archipelagoes do not represent a highly exceptional set of conditions, such as have very seldom prevailed in the history of the globe. According to the hypothesis here proposed, the essential conditions have included a hollowing (negative) movement of sea-level with subsequent heaping (positive) movement of sea-level, each movement being connected with that rare phenomenon, general glaciation. Atoll-forming periods may have been at least as rare as periods of such glaciation, and it is possible that only since the late Pleistocene has the first atoll archipelago come into existence. Single small atolls might have been formed at any time since the reef-building corals were evolved, but such groups of atolls as the Maldives, with their peculiar relation to the underlying plateaus, seem to demand special shifts of level. For explanation of existing atolls and barriers the preference is here given to a moderate tumular movement of the ocean, rather than to the enormous crustal displacements implied in the Darwin-Dana hypothesis. Correlating ice-caps and coral reefs, we use the great discovery of Louis Agassiz to support a principal conclusion of Alexander Agassiz. To the father, a zoologist, geology owes the glacial theory; to the son, a zoologist, geology owes a matchless collection of facts, which not only illuminate the theory of coral reefs, but also profoundly affect the problem of crustal deformation in the oceanic areas.

ART. XXXIII.—*The Probable Identity of Podolite with Dahllite*; by WALDEMAR T. SCHALLER.

A COMPARISON of the properties and chemical composition of podolite and dahllite shows them to be essentially identical. Dahllite was described in 1888 by Brögger and Bäckström,* and a description of it is given in Dana's System of Mineralogy, p. 866. Podolite was described by Tschirwinsky† in 1907, and the summary of the properties of the two minerals given below has been prepared from the printed descriptions.

Dahllite	Podolite
Occurs in crusts with fibrous structure, on apatite.	Occurs in crystalline masses or in prismatic crystals on phosphorite, also in spherulites of prismatic crystals.
Density is 3.053.	Density is 3.077.
Color is pale yellowish white.	Color is yellowish.
Uniaxial, negative.	Apparently hexagonal, crystals show optical anomalies, negative.
Double refraction and index of refraction slightly greater than that of apatite.	Double refraction somewhat greater than that of apatite.
Soluble in cold dilute acid with evol. of CO ₂ .	Mean index of refraction 1.635. Soluble in HCl with evol. of CO ₂ .
Composition $\left\{ \begin{array}{l} \text{H}_2\text{Ca}_{14}\text{P}_8\text{C}_2\text{O}_{39} \text{ or} \\ 2\text{Ca}_3\text{P}_2\text{O}_8 \cdot \text{CaCO}_3 \cdot \frac{1}{2}\text{H}_2\text{O} \\ \text{See below.} \end{array} \right.$	Composition $\left\{ \begin{array}{l} \text{Ca}_{10}\text{P}_6\text{CO}_{27} \text{ or} \\ 3\text{Ca}_3\text{P}_2\text{O}_8 \cdot \text{CaCO}_3 \\ \text{See below.} \end{array} \right.$

To better compare the two formulæ, they are given below with Ca given in constant amount.



The analyses of the two minerals are shown in the following table for comparison :

* Brögger, W. C. and Bäckström, H. Dahllite, a new mineral from Odegården, Bamle, Norway, Meddelanden från Stockholms Högskola. No. 77 in Öfr. Vet. Akad. Förh., 1888, p. 493. Abstracted in Zeit. Kryst. Min., vol. xvii, p. 426, 1890.

† W. Tschirwinsky. Podolite, a new Mineral, Centr. Min. Geol. Pal., 1907, p. 279. For some earlier but incomplete descriptions in Russian publication, see abstract thereof in Zeit. Kryst. Min., vol. xlv, p. 296.

Analyses.

	Dahllite	Podolite (crystals)	Podolite (crystalline aggregate)
CaO	53.00	51.15	51.31
P ₂ O ₅	38.44	39.04	36.44
CO ₂	6.29	3.90	4.18
H ₂ O	1.37	not det.	not det.
Fe ₂ O ₃	0.79(FeO)	3.04	1.73
Al ₂ O ₃	----	----	0.46
K ₂ O	0.11	----	0.45
Na ₂ O	0.89	----	0.66
F	----	0.00	0.26
Organic	----	----	0.56
SiO ₂	----	----	4.87
	100.89	97.13	100.92 (—0.08 O for F).

The above figures confirm the idea of the identity of the three substances analyzed. The CO₂ values for podolite are somewhat lower than that given for dahllite, but the differences are slight. Water was not determined, but it undoubtedly would be present in such a secondary mineral as podolite, and, moreover, a small amount must have been absorbed by the sample during its pulverization. The poor summations and the varying values in general for podolite lead one to suspect that further analyses of purer material, carefully made, would lead to slightly different results from those here given.

It is hardly possible, from the data at hand, to determine what is the correct formula for this interesting phosphate and carbonate of calcium. A formula analogous to apatite seems to be suggested by the evidence, and the 1.37 per cent of water given in the dahllite analysis can be explained by other means than that it is essential to the mineral, but the question as to the presence of essential water can only be settled by further analyses made with due consideration of all the influencing conditions. The name dahllite has priority over podolite by nearly twenty years, and the latter should, therefore, give way to the older name. What relation staffelite bears on these minerals can hardly be settled at this time, as the properties of staffelite are but poorly characterized.

Chemical Laboratory,
United States Geological Survey.

ART. XXXIV.—*The Identity of Stelznerite with Antlerite ;*
by WALDEMAR T. SCHALLER.

STELZNERITE was described as a basic copper sulphate by Arzruni and Thaddéeff* in 1899, their paper being edited by A. Dannenberg on account of the death of Arzruni. Prof. F. W. Clarke has recently called my attention to the chemical identity of stelznerite with a mineral analyzed by Dr. W. F. Hillebrand and named antlerite.† I have extended the investigation by examining optically some of the original type material of antlerite in the U. S. National Museum, for which privilege I would acknowledge the kindness of the Assistant Curator, Dr. J. E. Pogue. All the facts obtained point to the identity of stelznerite with antlerite.

On examining antlerite under the microscope it was seen to consist of a homogeneous aggregate of very minute crystals of a short prismatic habit and of a pale greenish color. The crystals extinguished parallel, but were too small for any determination of their optical orientation. The small crystals were not perceptibly pleochroic, but on the thicker ones a decided pleochroism was noticed, identical with that described for stelznerite. Parallel to the elongation of the crystals, the color was blue-green; normal thereto the color was yellow-green. The double refraction was high. These data are all in accord with those given for stelznerite. The values of the density, 3.93 (antlerite) and 3.884 (stelznerite, not corrected for admixed gypsum), agree closely.

Chemically, the two minerals are also seen to be identical, as first noted by Professor Clarke. The formula deduced for stelznerite is $3\text{CuO} \cdot 1\text{SO}_3 \cdot 2\text{H}_2\text{O}$ or $\text{CuSO}_4 \cdot 2\text{Cu}(\text{OH})_2$, while Hillebrand calculated the more complex one, $10\text{CuO} \cdot 3\text{SO}_3 \cdot 7\text{H}_2\text{O}$ or $3\text{CuSO}_4 + 7\text{Cu}(\text{OH})_2$ for antlerite. The analyses of antlerite are compared with those of stelznerite in the table below. Nos. 1 and 2 are Hillebrand's analyses of antlerite, with 8 and 6 per cent, respectively, of gangue deducted, and Nos. 3 and 4 are the analyses of stelznerite. No. 5 gives the calculated composition for the formula $3\text{CuO} \cdot 1\text{SO}_3 \cdot 2\text{H}_2\text{O}$, while No. 6 gives that for the more complicated formula $10\text{CuO} \cdot 3\text{SO}_3 \cdot 7\text{H}_2\text{O}$.

Though the first analysis of antlerite agrees better with the more complex formula, the second analysis agrees nearly as well

* Arzruni, A. and Thaddéeff, K. *Neue Minerale aus Chile, etc.*, Stelznerit, ein neues basisches Kupfersulfat. *Zeit. Kryst. Min.*, vol. xxxi, p. 229, 1899.

† Hillebrand, W. F. *Mineralogical Notes* (6. A Basic Cupric Sulphate), *Bull. U. S. Geol. Survey*, No. 55, p. 48, 54, 1889. Also given in Dana's *System of Mineralogy*, 6th ed., p. 928.

	Antlerite		Stelznerite		Calculated 3CuO.1SO ₃ .2H ₂ O	Calculated 10CuO.3SO ₃ .7H ₂ O
	1	2	3	4	5	6
CuO . . .	68·19	67·64	67·08	64·01	67·22	68·45
SO ₃ . . .	20·46	21·49	22·40	22·19	22·61	20·69
H ₂ O . . .	11·11	10·76	10·22	10·37	10·17	10·86
ZnO . . .	0·29	0·04	----	----	----	----
CaO . . .	0·05	0·04	0·06	0·57	----	----
Fe ₂ O ₃ . .	----	----	0·34	1·14	----	----
Residue . .	----	----	0·44	1·42	----	----
Moisture . .	----	----	----	·33	----	----
	100·10	99·97	100·54	100·03	100·00	100·00

with the simpler stelznerite formula. As no certain differences could be found in the optical properties and as the analyses agree so closely with one another, the two minerals stelznerite and antlerite must be considered as identical.

The characterization given stelznerite is much more complete than that of antlerite, and the formula deduced, $\text{CuSO}_4 \cdot 2\text{Cu}(\text{OH})_2$, is also simpler and is doubtless the correct one for the species. The name antlerite has, however, priority by ten years, and is the one to be adopted.

On careful investigation antlerite will doubtless be found to be much more abundant than is now thought, and much of what is now called brochantite may be found, on analysis, to be the closely related antlerite. Thus the artificial brochantite, described by Dana on page 926 of the *System of Mineralogy*, is in reality antlerite.

Chemical Laboratory,
United States Geological Survey.

ART. XXXV.—*On the Electromagnetic Emission Theory of Light*; by JACOB KUNZ.§ 1. *General considerations.*

THE problem of the nature of light is again a prominent one in theoretical and experimental investigations. Since Huygens, the wave theory of light has been found in such a perfect agreement with the phenomena that the older emission theory has been given up. Through Maxwell, the wave theory, so far based on an ether with elastic properties, has been given an electromagnetic interpretation, and a new field of phenomena, the electrical oscillations discovered by Hertz, bridged over the gap between electrical and optical phenomena. While the electromagnetic wave theory of light accounted for the groups of phenomena of reflection, refraction, interference, polarization, etc., difficulties were found in the explanation of the aberration, and of the experiments of Airy, Fizeau and Michelson-Morley. These phenomena, apparently contradicting themselves, have finally been interpreted from the standpoint of the principle of relativity. This principle tells us that the equations by means of which the laws of nature are expressed remain the same no matter whether the system of coördinates to which they are related is in motion or at rest. If this be so, then we are free to coördinate "ether" to the system of coördinates at rest or to the system in motion; in other words, we may picture to ourselves the ether at rest with respect to the system of coördinates in motion or with respect to the coördinates at rest. It appears superfluous and arbitrary to introduce an independent medium like ether in our electromagnetic theories. Thus the principle of relativity rejects the ether. On the other hand, energy of radiation appears to be materialized or inseparably connected with mass.

$$dE = dmc^2$$

The principle of relativity, giving up ether, points towards elements of electromagnetic energy, that have a certain analogy with material particles.

Independent of the principle of relativity, the theory of radiation of the black body has been developed by Lorentz, Planck, Larmor, J. J. Thomson and others. For long wave lengths the different ways of attacking the problem lead to exactly the same law,

$$dE = \frac{CT}{\lambda^4} d\lambda$$

but for the general law of radiation, and especially for short wave lengths, considerable difficulties have been encountered by every investigator. Planck in the theory of radiation assumes that the resonators gain or lose energy, not quite gradually by infinitely small amounts, but only by certain portions of a definite finite magnitude. The portions of energy depend on the frequency n of the resonator, so that

$$E = hn.$$

Planck's law shows a remarkable agreement with the experimental results and allows the determination of the fundamental quantities of nature; yet the mechanism of radiation is not revealed by the theory; it seems to me, that the resonators have but little analogy with the motions of the electrons in metals, which lead us to assume a connection between Röntgen rays and light. Moreover as far as our present knowledge goes, we have no experimental evidence of portions of electromagnetic energy of the form hn ; the experiments made on the photoelectric effect of sodium-potassium alloy, made by the author, show that the kinetic energy of the electrons emitted by this alloy is for a considerable range proportional to the square of the frequency of the incident light. On the other hand, it is well known that the optical properties of metals cannot be deduced quantitatively with any degree of accuracy from the electrical properties. It has been shown, however, by Hagen and Rubens that rays of light of wave length between 8 and 25 μ are absorbed to a degree that may be calculated with considerable accuracy from the conductivity.

H. A. Lorentz has based a theory of thermal radiation on this fact, which, however, is restricted to long wave lengths and coincides with the formula given above. This theory has been extended to short waves by J. J. Thomson, and I have shown what would be the acceleration of the electron in the case of collision with an atom. I came also to the conclusion that the energy of a monochromatic beam of light is proportional to the square of the frequency, a result which seems to agree with the present experiments.

Whereas the principle of relativity and the theory of radiation of Planck assume discontinuities in the emission and absorption of light, there are many optical phenomena pointing towards a corpuscular constitution of light and Röntgen rays. This is so much so, that a special corpuscular theory of Röntgen rays has been developed by Bragg, who considers them as made up of doublets of positive and negative particles. The main facts in the line of his argument are as follows: The number of atoms in a gas ionized by Röntgen rays is exceedingly small, while we should expect that all the atoms struck

by Röntgen rays in which the energy is distributed uniformly over the wave front, suffer the same change. When Röntgen rays pass through a region in which there are free electrons, they tend to make the electrons move in the same direction as those which produced the rays; in addition, the velocity of the electrons emitted from the metals under the action of Röntgen rays is about as high as the velocity of the primary electrons which produced the Röntgen beams; the number of electrons in the photoelectric effect depends only on the intensity of the light, not on the color, while their velocity depends only on the color and not on the intensity;—phenomena that we should expect from the point of view of an emission theory.

Thus without considering the emission of spectral lines and the phenomena of phosphorescence, we have a certain number of independent theories assuming a discontinuity in the emission of light, and a certain number of phenomena which have not yet been explained on the ground of the ordinary undulatory theory of light.

That theory will finally succeed in the explanation of the optical phenomena which is able to combine all experimental facts under one and the same point of view; the question then arises, which of the present theories may in the future be able to give the key to the secret of the mechanism of the phenomena of light?

Considering the wave theory and its electromagnetic interpretation by Maxwell as well established, we can only expect a very slight change in these theories as possible and compatible with the explanation of some new phenomena not yet explained. It seems to me as if the Faraday-Thomson conception of electrical forces or Faraday tubes may ultimately lead to a satisfactory theory of light. Sir J. J. Thomson,* following the idea of Faraday, ascribes to the lines of electrical force a certain physical reality, the tubes of force being endowed with mass, momentum and energy. In the paper mentioned above, J. J. Thomson considers the properties of the field if the electric force due to an electron is exerted in only one direction. It appears that the mass of the electron considered as a function of the velocity varies in the same way as is required by the principles of relativity. There are other ways of reasoning which lead to the same result, so that even if the formula

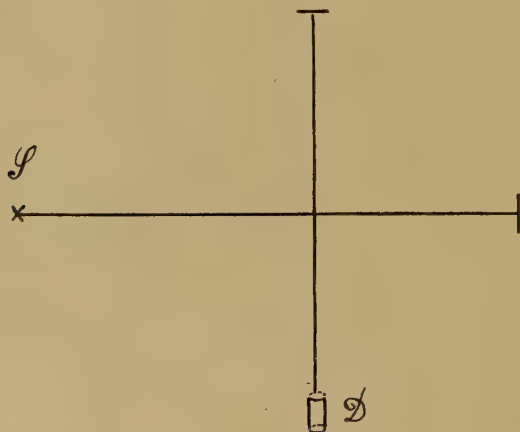
$$m = \frac{m_0}{\sqrt{1 - \frac{v^2}{c^2}}}$$

* Sir J. J. Thomson: On the Theory of the Structure of the Electric Field and Its Application to Röntgen Radiation and to Light. *Phil. Mag.*, xix, p. 301, 1910.

should be confirmed by experiment, we could hardly consider the result as a demonstration of the principle of relativity. The radius of an electron carrying a tube of force in one direction is much larger than the radius calculated on the assumption of a uniform distribution of the electric field around the electron. The effects produced when a moving electron is suddenly brought to rest, or when its motion is accelerated, are very similar to those calculated on the usual assumptions.

Of course, it is possible that there are a very large though finite number of Faraday tubes attached to the electrons, so that the electric field is finally little different from what we consider at present, and then we should in the limiting case have the same properties as we find in the usual electromagnetic wave theory of light. The great problem is to determine whether there is such a limit or a discontinuity in the space of an electric field. The theory of thermal radiation can be developed very nearly in the same way, as it is now, if we

FIG. 1.



assume that the field of an electron is spreading out from a center in one or in several directions, so that the change involved in the present theory of radiation would be very slight.

On the other hand, the explanation of the optical phenomena of aberration, of the Airy, Fizeau and Michelson-Morley experiment, would be very simple.

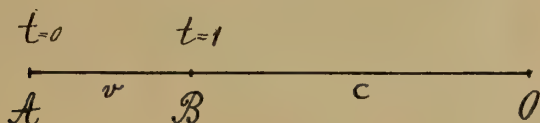
The theory under consideration makes an independent medium like ether unnecessary; it has features of the emission theory in common with the wave theory. The Faraday tubes

when in motion carry electromagnetic mass, momentum and energy with them. The phenomenon of aberration is explained in the same way as any of those phenomena which usually are taken as illustration of the phenomenon; a gun at rest and a boat in motion, or the rain drops falling on the windows of a train in motion. The illustrations lend themselves indeed better for the electromagnetic emission theory than for the ether wave theory. Airy's and Fizeau's experiment need a more careful consideration, but they have never caused serious difficulties, and I shall try to give an elementary theory in this connection a little later.

§ 2. *Michelson-Morley experiment.*

As we are in this theory dealing only with relative motion between the source and the observer, the interference fringes observed through the telescope D will remain the same whatever may be the relation between the optical apparatus and the earth. In the Michelson-Morley experiment the

FIG. 2.



relation between the source and the telescope remains unchanged; we can therefore expect no aberrational motion in the interference fringes. In this explanation no change of the units of time and space is required; and the explanation is very simple. But, on the other hand, the difficult question now arises as to the possibility of interference. The old emission theory of Newton cannot account for interference, but the electromagnetic emission theory, involving vibrating Faraday tubes connecting with the oscillating electron, seems to provide a means of explanation of interference. If the number of Faraday tubes connected with an electron were very large, we should expect the same phenomena of interference as in the wave theory. And if there were only two tubes attached to the electron, spreading out in opposite directions, J. J. Thomson points out that even in this case interference might be possible, because the vibrations along a considerable number of tubes coming from a luminous body must have their phases related in a definite way. A vibration from an electron will strike against other electrons and excite vibrations, which are in definite phase relations with the primary vibrations.

§ 3. *The Doppler effect.*

Let a source of light be moving with velocity v along a line AO, emitting disturbances of frequency n in all directions; the velocity of propagation will be equal to $c + v$; after one second the first disturbance emitted in A will reach the observer in O. If we start counting the time in the moment in which the source is in A, then in $t = 1$ the source will be in B and emit the n th disturbance. This disturbance will reach the observer after a time $\tau = \frac{c}{c+v}$. Hence the observer receives n disturbances in the time interval $\frac{c}{c+v}$, or n' disturbances per unit time:

$$\begin{aligned} \frac{c}{c+v} : n &= 1 : n' \\ \frac{n'}{n} &= \left(\frac{c+v}{c} \right) & n' \lambda' &= c+v \\ & & n \lambda &= c \\ \frac{\lambda'}{\lambda} &= \frac{c+v}{c} \cdot \frac{n}{n'} = 1 \end{aligned}$$

or the wave length remains unchanged.
In the case of sound we have:

$$\frac{\Delta \lambda}{\lambda} = \frac{v}{c}$$

and this formula is also used in spectroscopy for the determination of the velocity of stars.

The principle of relativity leads to the expression:

$$\frac{n'}{n} = \frac{\sqrt{1 - \frac{v^2}{c^2}}}{1 - \frac{v}{c}} \quad n' \lambda' = n \lambda$$

while the emission theory here sketched gives the result:

$$\frac{n'}{n} = \frac{c+v}{c}$$

On the other hand, the principle of relativity maintains that the velocity of light is always the same, c , whatever be the velocity of the source or of the observer. The electromagnetic emission theory holds that the velocity of light given out by a

source of light in motion varies with the direction of propagation of light. In the direction in which the source of light is moving, the velocity of light is equal to $c + v$, in the opposite direction equal to $c - v$, in the perpendicular direction, c .

The experiment should be able to decide between these alternative theories. Among different possibilities the canal rays lend themselves perhaps in the first place to an experimentum crucis. We are here dealing with positive particles whose velocity in hydrogen may be as high as 10^8 cm./sec., or only 300 times smaller than the critical velocity, c , of light. If it could be shown that the velocity of light given out by those moving particles is the sum $c + v$, the principle of relativity would disappear and the electromagnetic emission theory would be victorious. If the velocity of these positive particles was found to be c in all directions, the emission theory would have to disappear forever.

The velocity of the source of light in the canal rays determined by means of the Doppler effect varies from 30–80 per cent of the velocity computed from the cathode fall of potential and the value e/m . A simultaneous determination of the velocity of canal rays by means of the Doppler effect and by means of the electrostatic and electromagnetic deflection would be very desirable.

§ 4. *Interference.*

The emission theory suggests the possibility of a difference in the interference of two beams issuing under a large angle from the same source and the interference due to two beams issuing in the same or very nearly the same direction. The light from two sources is not susceptible of interference, while interference occurs in a beam from one source, because there are phase relations between the oscillations in the Faraday tubes, issuing from one source. It may be that for this reason N. Campbell* has not yet succeeded in searching after a difference in the "events" of the photoelectric effect, due to two beams separated by interference.

If, however, the energy travels out from the source along certain directions, we should finally be able to detect, for instance in the case of Röntgen rays, a scintillation effect, or at least discontinuities in the phosphorescence of a sensitive screen. It is possible, too, that one screen could show such discontinuities while another does not, because if a molecule is made a source of light, it might affect the neighboring molecules to emit light also; and in this way a discontinuity, originally present, might be masked. Perhaps the idea of

* N. Campbell, Discontinuities in Light Emission. Proceedings of the Cambridge Philosophical Society, vol. xv, p. 310, 1909.

Campbell's experiment might be tested by means of a Röntgen bulb rather than by a source of light. At all events, there are two important facts which show that if the phenomena of light can be explained by an emission theory, the neighboring trains of oscillations issuing from a source of light must be in a very close phase relation. The path difference between two beams that can interfere with each other can amount to over 100,000 waves and the light, susceptible of interference, may be exceedingly weak. If light or Röntgen rays were able to produce mechanical effects, for instance to disintegrate metals, then the velocity of the particles emitted ought to be independent of the intensity of the light, and the quantity of disintegrated product ought to be proportional to the quantity of light.

§ 5. *Photochemistry.*

A great field of optical phenomena, including the photographic processes, are still awaiting explanation. The fundamental law of the photochemical action could be deduced at once from the electromagnetic emission theory of light. The photochemical action is the same when the product of time and intensity of the incident light remains the same. Exactly the same law holds in the photoelectric effect; the number of electrons emitted from a metal plate under the action of light and Röntgen rays depends only on the quantity of light impinging. These laws are of the same type as Faraday's law of electrolysis. And as in the photoelectric effect and in the ionization of gases the number of electrons or ions is only very small, so also is the number of molecules by exposing a photographic plate to light exceedingly small, whereas from the wave theory, where the electromagnetic energy is distributed uniformly over the wave-front, we should expect that all molecules should behave in the same way.

The velocity of the photochemical reactions does hardly depend upon the temperature; the ionization of gases also is independent of temperature; the mechanism of these phenomena appears to be of the same nature.

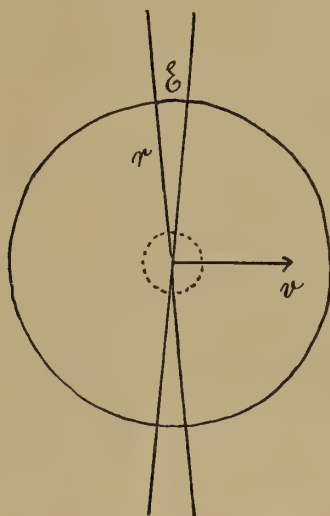
Now the electrical force in a sunbeam is about 10 volts per centimeter and about 0.5 volts per centimeter in the pulse of the Röntgen rays, while the electrical force required to drag an electron out of an atom of gas is about $2 \cdot 10^9$ volts per centimeter, corresponding to the work necessary to produce an ion, which is equal to $4,410^{-11}$ ergs. It is as a rule said, that the ionization of gases, the photoelectric effect and some of the photochemical reactions are due to resonance processes; but it can be shown that it would require several minutes before ultra-violet light could produce an ion in this way and it would require about 200 days of action of Röntgen rays before one

single ion could be formed. Resonance on the ground of the continuous ether theory does not account for ionization. That a considerable amount of work is also required to drag an electron out of a metal follows from a recent investigation of the spark discharge by W. W. Williams, who found no spark in a distance of $1,5\lambda$ of sodium light when the potential difference was as high as 300 volts.

§ 6. *The intrinsic magnetic field of ferromagnetic substances.*

The hypothesis of the intrinsic or molecular magnetic field due to P. Weiss has thrown a good deal of light on the magnetic properties of the ferromagnetic substances. The molecular field accounts for the very high value of the magnetization of iron, nickel and cobalt. There are some discrepancies between theory and experimental results; for instance, is the law of approach of the intensity of magnetization to saturation not that required by theory, except for cobalt and the variation of the intensity of magnetization with the temperature at very low degrees, does not quite follow the curve given by theory.

FIG. 3.



This fact is connected with another result of recent investigation on magnetism, showing that the paramagnetic susceptibility is not in general inversely proportional to the absolute temperature, as was assumed by Curie and Langevin, who considered therefore the moment of an elementary magnet as independent of the temperature. These results make a certain modification of the theory necessary, but in the main features

the agreement between the theory and the experimental results is so close that the hypothesis has at least the value of a working hypothesis. It has been shown by the author of this article* that the theory allows us to determine the absolute values of the moments of the elementary magnets of iron, nickel and magnetite, and that we can determine in this way the elementary quantity of electricity; the value e obtained in this way agrees well with that given by Rutherford.

While the moment of the elementary magnet can be accounted for by the usual electron theory, it seems almost impossible to account for values of the molecular field as high as 6,560,000 absolute units in iron and 14,300,000 in magnetite.

For if we assume the frequency n of an electron equal to that of sodium light $n = \frac{1}{2} 10^{15}$, the velocity of the electron revolving in a circle would be equal to

$$v = 2\pi nr$$

where r is the radius of the orbit of the electron which we shall assume to be of the order of magnitude 10^{-8} cm

$$v = 3, 14 \cdot 10^7 \text{ cm}$$

The electric force at E is equal to $\frac{e}{r^2}$ under the usual assumption of uniform distribution of the Faraday tubes around the electron $E = \frac{1,55 \cdot 10^{-20}}{10^{-16}} = 1,55 \cdot 10^{-4}$.

If we now assume that the tubes spread out in the form of narrow cones in only two directions so that the part of the surface of the sphere cut out by the cones is $1/1000$ of the whole surface, then the electric force in E will be 1000 times larger than before, assuming that the properties of the isolated tubes are the same as those possessed by a tube forming part of the continuous electric field. $E = 1,55 \cdot 10^{-1}$. If now the tube is moving, there is a magnetic force acting at each point in the tube, the direction of the magnetic force being at right angles to the plane containing the electric force and the direction of the motion of the tube at the point, the magnitude of the magnetic force being the product of the electric force and the component of the velocity at right angles to this force. If the angle is equal to 90° , the magnetic force H will be equal to

$$H = E \cdot v = 3,14 \cdot 10^7 \cdot 1,55 \cdot 10^{-1}$$

$$= 4,9 \cdot 10^6 \text{ absolute units.}$$

In this way it would be easy to account for the very high values of the molecular field of the ferromagnetic substances.

Laboratory of Physics, University of Illinois,
Urbana, July 14, 1910.

* J. Kunz : The Absolute Values of the Moments of the Elementary Magnets of Iron, etc. *Physical Review*, vol. xxx, p. 359, 1910.

ART. XXXVI.—*Some Apparent Variations of the Vertical observed at the Cheltenham Magnetic Observatory* ;* by JOHN E. BURBANK.

THIS paper deals with some slow period changes of level of the piers on which the Omori horizontal pendulum seismograph has been mounted at the Cheltenham Magnetic Observatory.

From November, 1904, to October, 1907, both components were mounted on stone piers in the north room of the variation observatory.† In October, 1907, the entire instrument was moved to a new location and mounted on a massive concrete pier.‡ A comparison of the diurnal oscillation of level and also the changes of level due to temperature variations, in the two places, shows that the magnitude and direction of these effects are to a large extent local.

The diurnal oscillation of level has been noted at many seismological stations. Professor J. Milne§ has studied this effect in Japan and elsewhere and has observed it in the soil 12 feet below ground level, but did not observe it when the instrument was mounted on the solid rock in a cave. He found the diurnal wave hardly appreciable in a wood where the trees protected the pendulum house from the direct effects of the sun. At all stations where the ground was covered with trees or buildings more upon one side of the station than upon the other, the diurnal waves were large, and often differed in phase. At most stations on wet and cloudy days diurnal waves were absent.

E. von Rebeur-Paschwitz|| compared the diurnal oscillation of the surface of the ground at three places—Wilhelmshaven, Potsdam, and Puerto Orotavo, Teneriffe; he found the effect most pronounced in the east-west direction, and comparatively small in the north-south direction.

At Wilhelmshaven the pier was erected in the cellar of the Naval Observatory, the surface of the ground is marshy, with a layer of 2 to 3 meters of clay, and below this sand to a great depth.

At Potsdam the pier was mounted in the cellar below the

* Communicated by permission of the Superintendent U. S. Coast and Geodetic Survey. Read before the Philosophical Society of Washington, Jan. 29, 1910.

† For description of the Observatory see Appendix No. 5, Report of the Superintendent U. S. Coast and Geodetic Survey, 1902; also *Terrestrial Magnetism*, vol. viii, pp. 11–30, March, 1903.

‡ See *Terrestrial Magnetism*, vol. xiii, pp. 1–20, March, 1908.

§ J. Milne, *Movements of the Earth's Crust*, *Geographical Journal*, vol. vii, p. 229, March, 1896.

|| See reprint in *British Association Report*, 1893.

east tower of the Astrophysical Observatory, the soil being sand to a great depth.

At Puerto Orotavo the seismograph was mounted at ground level on the cement floor of a small building on the side of Pico de Teyde about 18 kilometers from the summit.

The diurnal range of oscillation of the plumbline (apparent variation of the vertical) at these three places agrees remarkably well with the ranges of those elements which are a measure of the intensity of the solar radiations; the actual range differing, however, between the three places. The times of maximum east and west displacements also differ.

In fig. 2 are given curves for the diurnal oscillation of the plumbline on clear days for the three places: (O) Puerto Orotavo, (P) Potsdam, and (W) Wilhelmshaven. Negative ordinates indicate motion of plumbline toward east, and positive ordinates motion toward west. An increase of temperature caused deviation toward the east in each case, the amount at Wilhelmshaven being far the largest of the three. Barometric variations caused tilting at Wilhelmshaven and Puerto Orotavo but not appreciable at Potsdam.

Dr. J. R. Sutton* found that the seismograph piers at Kimberley, S. Africa, showed a diurnal variation of level with a range of from about 2 seconds of arc in summer to about 4 seconds in winter. The maximum westerly elongation occurred about 5h. 30m. A. M., and the maximum easterly about 4h. 15m., the median positions a little before 11 A. M. and 9h. 30m. P. M.

Mr. B. M. Varney† studied the diurnal variation at Cambridge, Mass., and found that it occurred only on days when the sun shone. The E-W component showed a tilting toward the east during the forenoon, which died out about noon and was followed by a tilting toward the west during the afternoon. The N-S component showed a tilting toward the south during the forenoon, and to the north later in the day. It was much smaller than the E-W motion.

The existence of this diurnal oscillation of the level has been noted by Ehlert,‡ at Strassburg, at a depth of 5 meters below the surface; by Denison,§ at Victoria, B. C.; Lagrange, at Uccle||; Claxton, at Mauritius,¶ and Wallis,** on the Milne

* Preliminary Note on the Diurnal Variation of Level at Kimberley, Transactions Royal Society of S. Africa, vol. i, pt. 1, pp. 303-309.

† Some Long-period Deviations of the Horizontal Pendulum at the Harvard Seismographic Station, Science, Feb. 11, 1910.

‡ Beiträge zur Geophysik, iv, p. 70.

§ The Effect of Atmospheric Pressure upon the Earth's Surface, Journal of the Royal Astronomical Society of Canada, Nov.-Dec., 1908.

|| Périodicité Sismique Bulletin de la Société Belge d'Astronomie, July, 1904.

¶ Results of Mag. and Met. Observations made at Mauritius in 1906.

** Not yet published.

seismograph, at Honolulu Magnetic Observatory. It has also been noted at Sitka, Alaska, at the Weather Bureau in Washington, and doubtless at nearly every seismological station in the world.* Dr. Hecker† states that it was not entirely eliminated at a depth of 25 meters below the surface at Potsdam.

This diurnal oscillation of the surface of the ground appears to be a general effect which does not admit of easy explanation. It appears, however, in some cases to be largely conditioned by the immediate surroundings of the pier.

The seasonal and annual variation of level has been studied by Paschwitz, Denison, Wallis, Hecker, Klotz‡ and numerous others. The results for the stations on the continental areas appear irregular and are not easily explained.

An attempt to determine the annual range of level at this observatory shows that it is comparatively large, but the results are far from satisfactory. The screw which controls the lateral movement of the cylinder, spacing successive lines 3 millimeters apart, does not have uniform pitch and successive days' records are not always controlled by the same part of the screw. This error of the screw prevents a study of the long-period variations of level, but is not great enough to seriously affect results extending over a period of one or two weeks.

The possible effect of variations of atmospheric pressure on the change of level has been studied by von Rebeur Paschwitz,§ who noted at Wilhelmshaven a deviation of level of 0.29" of arc for one millimeter variation of the barometer. This extraordinary fluctuation was attributed to the marshy, spongy nature of the ground. His later observations at Strassburg show that the effect of barometric variations there is uncertain.

Professor Omori describes three cases of remarkable tilting of the ground in Japan during storms. At Tokyo, on Oct. 10-11, 1904,|| when an extreme oscillation of level amounting to 3.5 seconds of arc occurred in a few hours, and again on Jan. 10-11, 1906,¶ when the extreme range amounted to 2.87 seconds of arc, and at Mito, some distance northeast of Tokyo on March 23, 1907,** when a range of 3.7 seconds of

* The references in connection with this paper are very incomplete, as they include only the few which have come to my attention.

† Beobachtungen an Horizontalpendeln über die Deformation des Erdkörpers unter dem Einfluss von Sonne und Mond, Veröff. des Kgl. Preussischen Geodätischen Institutes, Neue Folge Nr. 32, 1907, 95 pages.

‡ Report Chief Astronomer (Canada), 1907. Appendix 2, Ottawa, 1908.

§ Beiträge zur Geophysik, xi, p. 334.

|| Publications of the Earthquake Investigation Committee, No. 21, pp. 5-8.

¶ Bulletin Imperial Earthquake Investigation Committee, vol. i, No. 4, August, 1907.

** Bulletin Imperial Earthquake Investigation Committee, vol. ii, No. 1, March, 1908.

are occurred between 10 A. M. and 5 P. M. Professor Omori considers that these remarkable variations are in large part due to an abnormal rise of the sea under the storm center in excess of the amount necessary to compensate the barometric pressure.

This barometric effect has been studied in this country by Denison, Varney and Klotz. Denison's results at Victoria, B. C., extend over a period of 11 years and present some very interesting and valuable information.

In 1908 the records of the seismograph at this observatory for about two years previously were very carefully examined for indications of changes of level due to the passage of areas of high and low pressure across the eastern part of the United States and no satisfactory relation was observed.

The more or less pronounced variations during this period showed a fairly systematic agreement with the temperature changes accompanying the passage of these low or high areas. These temperature changes were often such as to cause a pronounced tilting away from the storm center (low) and at other times such as to cause an equally pronounced tilting toward the center of low pressure. The direction of the tilting did not change appreciably as the center advanced from west to east, except as the temperature changed.

While the barometric variations produce an effect which can be readily measured by sufficiently sensitive instruments, it is in many locations entirely obscured by changes of level due to causes of a local nature. This yielding of the earth's crust to variations of barometric pressure is discussed by Sir G. H. Darwin.*

A general formula for the tilting shown by a horizontal pendulum can be derived as follows: Let M be the steady mass at the end of the horizontal strut x , see fig 1. This strut ends at A in a hardened steel, cup and point bearing. The weight of M is supported chiefly by two guy wires, BM , attached at opposite sides of M , and joined, near B , in a yoke which terminates at B in a point and cup bearing, similar to that at A .

Let θ be the angle between AB and the vertical.

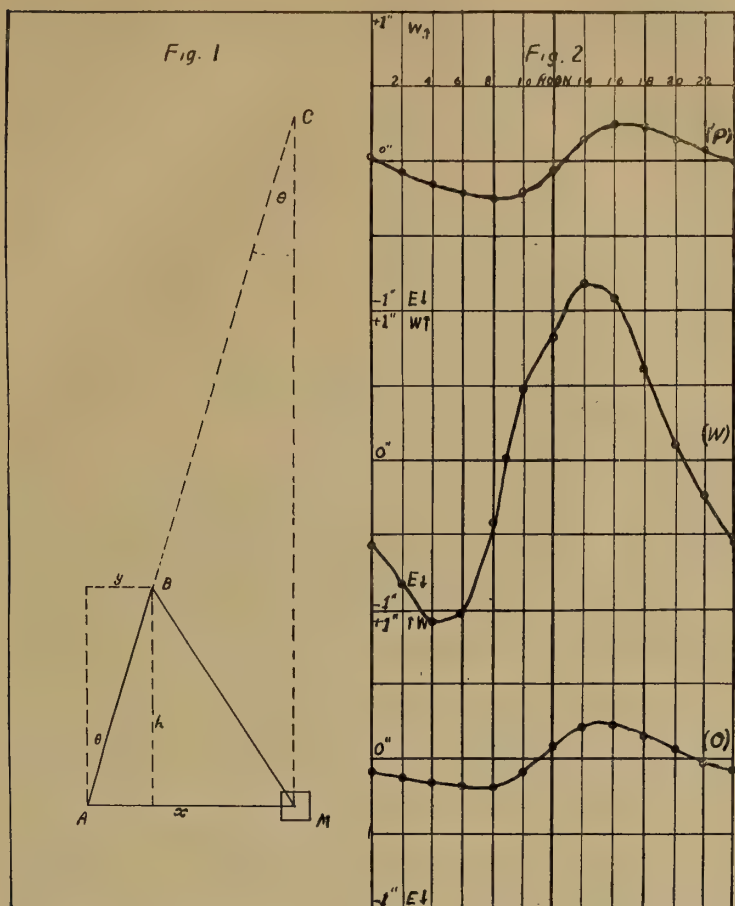
x distance A to M (center of mass of suspended system).

h vertical distance of B above horizontal plane through A .

Since x is usually horizontal and θ is always a very small angle, the distance x can be taken as the approximate length

* Scientific Papers, vol. i, pp. 444-450; or Phil. Mag., vol. xiv, 1882, pp. 409-427; or British Association Report for 1882, pp. 106-119.

FIGS. 1, 2.



of the simple pendulum by placing AB horizontal. Let t be the period of the pendulum so placed.

The distance CM is the length of the equivalent simple pendulum, namely, one having the same period, T , as the horizontal pendulum.

$$(1) \quad \sin \theta = \frac{x}{CM} = \frac{t^2}{T^2}$$

From the measured value of x and the observed value of T , θ can be readily computed.

If the pier or pedestal be tilted in a plane normal to AM through the angle i , the center of mass, M , will move through

the distance z to a new position of equilibrium. The displacement of M is the same as that of a simple pendulum of length CM supported on the same pier.

$$(2) \quad \text{Hence } \sin i = \frac{z}{CM} = \frac{4\pi^2 z}{gT^2}$$

$$(3) \quad \text{or} \quad z = \frac{g}{4\pi^2} T \sin i. \quad (\text{Parabola.})$$

For a given value of i , z varies directly as T .

If n be the multiplying ratio of the writing arm and z' the displacement on the record,

$$(4) \quad z' = nz = \frac{ng}{4} T^2 \sin i, \quad (4) \text{ can also be written}$$

$$(5) \quad z' = xn \sin 1'' \frac{T^2}{t^2}, \text{ which is the form used by Professor}$$

Omori.*

The pendulums used here have x about 75^{cms} and t about 1.74 seconds, and when T is 28 seconds and n equals 10 a change of 1'' in the level of the pier corresponds to a lateral displacement of 9 millimeters on the record sheet. The cylinder revolves once per hour, and also moves laterally at the rate of 3 millimeters per revolution, so that the pen traces a spiral, the lines under normal conditions being spaced 3 millimeters apart. Any tilting of the pier or pedestal in the line of free motion of the pendulum would produce a crowding together or separating of these lines. The amount of tilting during short intervals of time, say 3 or 4 days, can be quite accurately determined by measuring the excess or defect of the spacing over the normal amount, 3 millimeters per revolution.

A careful study of the records for the period Jan. 1906 to Oct. 1907 shows that the piers on which the two components were mounted were tilted by pronounced changes of temperature. These piers were exceptionally well protected against sudden changes of temperature, and the building would further protect the ground around the piers from very sudden changes of temperature.

With gradual rise of temperature the top of the N-S pier tipped toward the north and top of the E-W pier toward the west. With falling temperature both sets of piers returned toward their normal positions.

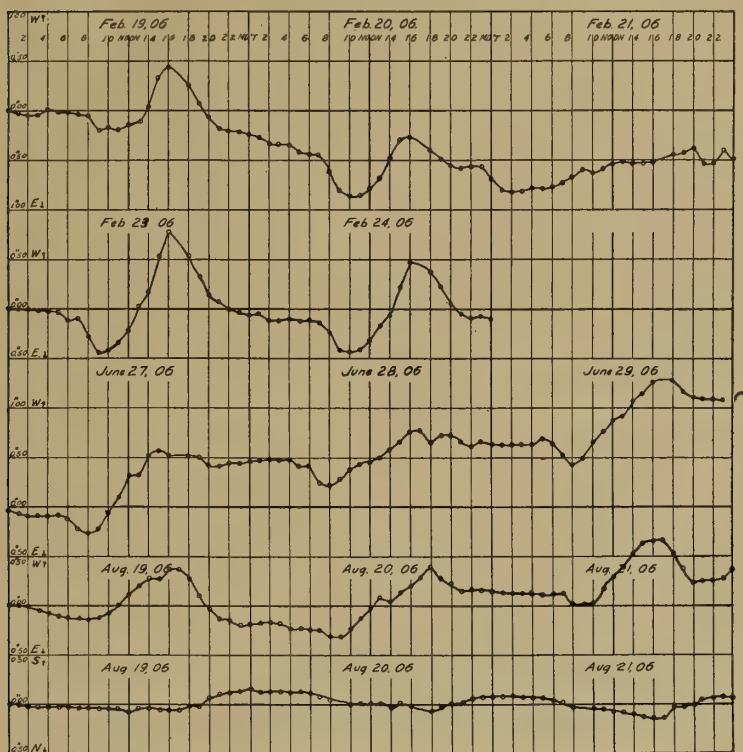
A study of the diurnal tilting during Jan. 1906 to Oct. 1907 shows that it occurred on the E-W component on all clear days. This relation was so definite that it was possible to tell by the

* Publications of the Earthquake Investigation Committee, No. 21, pp. 5-8.

appearance of the record if the sun shone for a couple of hours during the day. No definite tilting could be observed on the N-S component. This may be due in part to the fact that the absolute observatory is placed directly south of the variation observatory, thus shading the ground on that side.

In fig. 3 are shown a few curves of the E-W component from the records of the year 1906. The lowest curve is for

FIG. 3.



the N-S component and shows the inappreciable amount of tilting it experienced.

Of the eleven days for which curves are given, Feb. 21 was cloudy, Aug. 20 and 21 partly cloudy, and all others were clear.

In these curves a negative ordinate or motion downward indicates a movement of the top of the W-E pier toward the east and of the N-S pier toward the north; movements upward corresponding to tilting toward the west and south.

The curves in figure 3 show that shortly after sunrise, on clear days, the W-E pier began to tip toward the east, reaching its maximum east deviation about 10 A. M.; it then reversed its motion and tipped toward the west, reaching maximum west deviation about 4 P. M. (16 hrs.), and then slowly returned to its normal position. It should be noticed that all the curves show the slow tilting due to gradual changes of temperature, on which these diurnal tiltings are superposed. The tilting begins earlier in summer than in winter, but the times of maximum east and west deviation do not vary greatly with the season. The range of motion is greatest in winter, the yearly average being about one second of arc. Any cloudiness or other condition which diminishes the intensity of the sun's radiation tends also to diminish the range of tilting. This is especially noticeable in cases of fog in the morning.

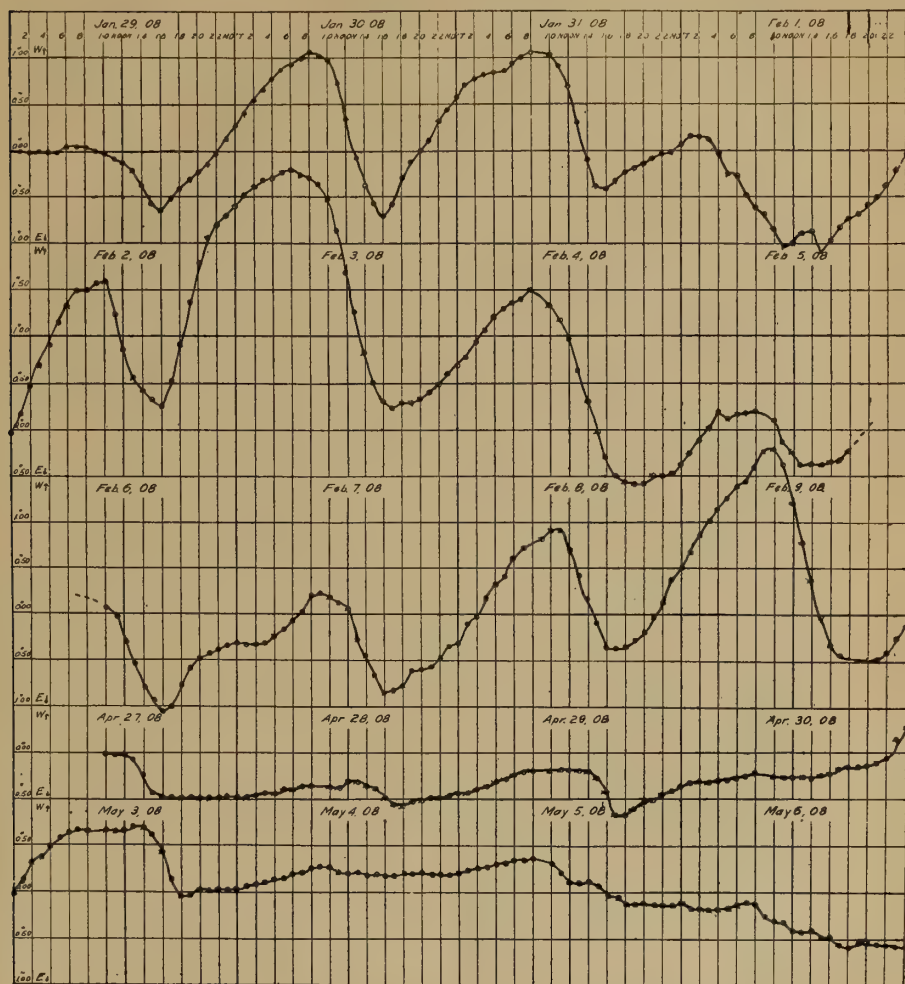
The results of this tilting of the E-W pier have been recently confirmed by a similar seismograph adapted to show only the slow tilting of its pier. The heavy mass, M, carried a vane dipping in a dish of glycerine, so that all rapid oscillations were damped out. A pointer fastened on M was in contact with a small arm extending from the mirror frame of an Eschenbagen magnetic variometer. The mirror was carried by a quartz fiber and the torsion head was turned so that the arm and the pointer remained in contact. Any movement of M caused the mirror to turn. The record was obtained on bromide paper in the same way that the magnetic elements are recorded. The sensitiveness was such that any motion of M was magnified 300 times. Records were obtained from Aug. 28 to Oct. 12, 1908, and they confirm the general results stated above. They show clearly the great variation in amount of tilting on different clear days, depending apparently on the intensity of the solar radiation.

Since October, 1907, the seismograph has been mounted on a concrete pier in the new seismograph house. Here the tilting due to external temperature changes has been larger than in the former location. When the external temperature rises the pier tilts toward the east and south, directly opposite to the effect in the variation observatory. The diurnal tilting is inappreciable on the N-S component, but is well marked on the E-W component. It differs essentially from that observed in the variation house, consisting of a tilt toward the east, beginning about 10 to 11 hrs. and reaching a maximum east deviation about 16 to 18 hrs., and then returning slowly to its normal position. The diurnal oscillation is in this case a deflection to the east and return. The building is placed in the side of a gravel bank so that the west side only is exposed, all other sides being banked to the eaves with gravel. There

does not appear to be any consistent relation between the tilting of the piers in the two locations, but each appears to be influenced by local causes which are somewhat obscure.

Some curves are given for the W-E component (see figure 4)

FIG. 4.



showing some extreme examples of this tilting effect during cold winter days, Jan. 29th-Feb. 9, 1908; and also the less marked effect during mild weather, in April and May.

The pronounced tilting during the period Jan. 29-Feb. 9,

1908 is due partly to solar diurnal effect and partly to large temperature variations occurring at this time, when the nights were very cold. Of this period Jan. 31st and Feb. 1st were partly cloudy and Feb. 5th was cloudy. During the period in April and May, April 27th was cloudy in the p. m., April 28th was cloudy, April 30th cloudy, and May 3d, 4th, 5th, and 6th cloudy. April 29th was clear.

An interesting effect which has been frequently noticed during the winter of 1908-9 appears as a very minute tilting of the pier back and forth of very small amplitude and irregular period of about a minute. This occurs at times when the ground is frozen and is especially noticeable when it is freezing or thawing.

No complete explanation of the diurnal tilting is evident, yet certain facts are apparent. The tilting is not due to any change in the temperature of the seismograph itself, or of the pier, since temperature changes inside the variation observatory are insignificant. While the temperature changes in the new seismograph house are often as great as 1° C. per day, yet on two occasions a change of 2° or 3° C., produced by a lamp in the room, had no appreciable effect on the tilting of the pier. The actual tilting differs in amount from place to place, yet it appears to be a comparatively common effect.

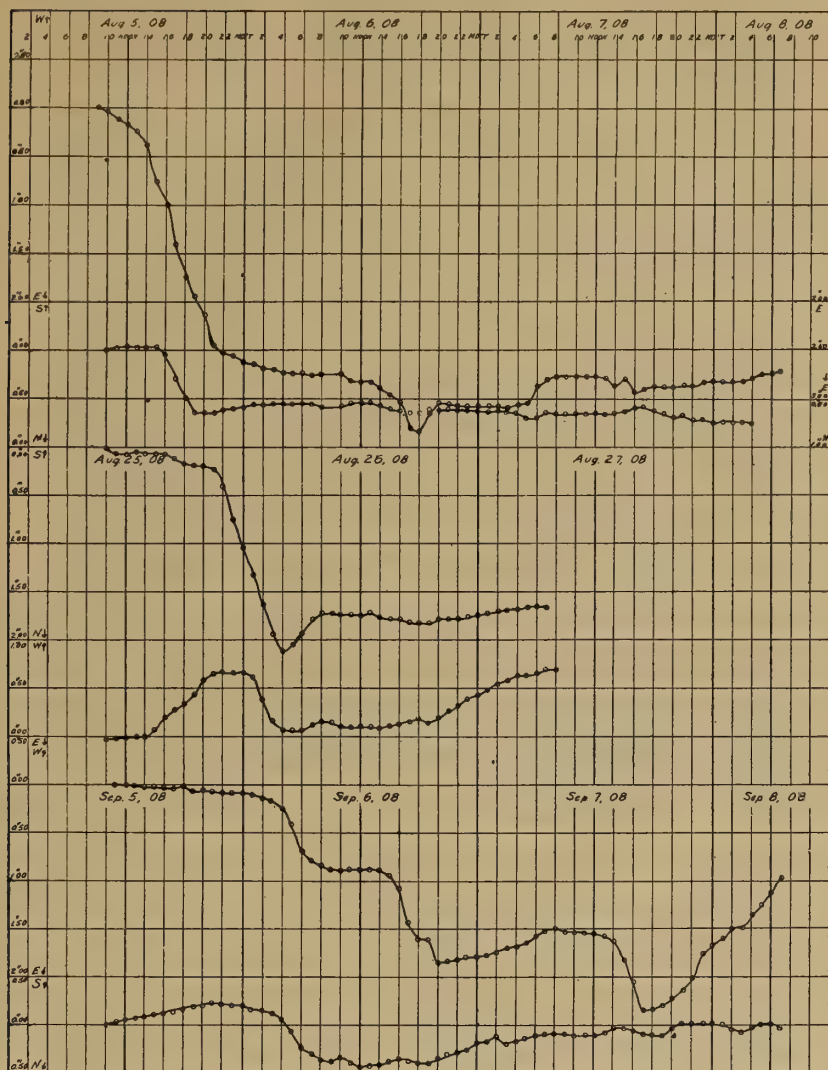
Tilting due to rainstorms.—Sudden and heavy downpours of rain do not appear to cause any decided tilting effect on the piers in the variation building. A heavy rain has, however, a decided effect in tilting the pier in the new seismograph house.

It is interesting to note that this pier always tilts toward the northeast, the E component of motion being much greater than the N component. This is possibly accounted for by the surface formation at the south and west of the house. A slight depression beginning about 50 yards southeast of the building extends around the south and west sides, being about 50 yards wide on the west side of the observatory. Up to this point its slope is very gradual and its surface is here on a level with the bottom of the pier. From this point the depression falls away more rapidly toward the north. About 50 yards northwest of the house are several springs and the soil beyond this point may be regarded as saturated with water.

The house is placed in the edge of a gravel bank, the top of which is about 15 to 20 ft. above the level of this depression, and the movement of the pier is the same as if the bottom of this depression was expanded by the water and pressed against the side of the hill.

Figure 5 gives some curves of tilting due to sudden rainstorms. That on August 5th is the best example. Between 3:30 p. m. and 5 p. m., 2.95 inches of rain fell. The ground

FIG. 5.



was very dry, as very little precipitation had occurred for several weeks. The effect was to cause a sharp tilt toward the E, which was superposed on the solar diurnal tilt already occurring, and a smaller but equally sharp tilt toward the N. The effect of the water was gradual but had reached its full amount in about 5

hours. The total displacement was about 3.00'' of arc toward the east and 0.6'' toward the north, and this condition remained practically unchanged for over 2 days. It would appear from this that the drying out of the ground had caused the pier to tip toward the southwest and the return of moisture caused a reverse movement.

Again on Aug. 25th about midnight there was a heavy rainfall the effect of which was superposed on a tilting due to the temperature change. This temperature change was such that the pier was moving toward the northwest and the rain caused motion toward the northeast, accentuating the motion in the north component and decreasing and reversing that in the E-W component. In this case there appears to have been a partial recovery due possibly to the fact that the soil had received, from recent rains, nearly its normal moisture content, and the excess soon ran through.

On September 6th during the early morning hours a heavy downpour of rain (2.34 inches) occurred. This produced a tilting of the pier toward the northeast, but the effect was superposed on a gradual temperature change and was much less than on Aug. 5th. Partial recovery appears to have occurred during the next two days. August 6th, 7th, and 8th were cloudy, as was August 25th also. September 6th was cloudy during the morning while September 7th was clear. The solar diurnal tilting occurred on September 7th, and it would appear that a saturated soil may modify but apparently does not prevent this effect.

The return of the pier to its former position appears quite marked on September 7th, and it is possible that its failure to return in the first two cases was due to the cloudy weather, which prevented the ground from being dried out.

ART. XXXVII.—*The Tombador Escarpment in the State of Bahia, Brazil*; by JOHN C. BRANNER.

IN a preceding article I have described the geology of the Serra do Mulato near Joazeiro, state of Bahia,* in that article mention was made of the Tombador beds of quartzite that cap many of the mountains along the Rio São Francisco above Joazeiro. The present article describes briefly the geology of the Serra do Tombador near the city of Jacobina, from which that series of rocks was named, and the relations of those beds to older and newer rocks through the diamond regions of Bahia.

The southern extremity of the Serra do Tombador† is known locally as the Serra da Gamelleira, and is about twenty kilometers southeast of the mining town of Ventura. This southern or Gamelleira portion is cut off from the main Tombador range by Rio Jacuipe about fifty kilometers southwest of the city of Jacobina. From the Jacuipe water-gap the Tombador range runs a little east of north, always parallel with but entirely distinct from the Jacobina range, and forming the eastern rim of the Salitre Valley drainage, to the falls of Rio Salitre, some thirty-five kilometers south of the city of Joazeiro. It has, therefore, a total length of nearly three hundred kilometers on an air line.

The geology of the Serra do Tombador has long been a veritable stumbling-block in Brazilian geology. The difficulties it has created, however, are not due to the nature of its geology, but rather to the fact that it is in a distant part of the interior difficult of access, and because the information regarding its geology is scanty and consequently liable to misinterpretation.

The earliest notes, and indeed the only ones, on the geology of the Serra do Tombador proper were written by Dr. J. A. Allen, about 1868 and published in 1870 in Hartt's *Geology and Physical Geography of Brazil* at pages 309–313. Mr. Allen explains in his paper, however, that his trip across this region was made hastily, "the geology of the country being to me at the time a matter of secondary interest" (p. 309). Many of his observations and notes are remarkably clear and

* This Journal, Oct., 1910, pp. 256–263.

† The Portuguese word *tombador* means tumble-down or roll-down. It is often applied to precipitous places on the side of a hill or mountain, and also to mountains themselves. In the state of Bahia alone there are two prominent ranges bearing this name. One of them is on the southeast side of the Rio São Francisco just south of Remanso, the other—the one here described—is thirty kilometers west of the city of Jacobina.

graphic, but they are necessarily fragmentary, and do not pretend to give a comprehensive idea of the geologic structure. Indeed it is not to be expected, under such circumstances, that Mr. Allen's paper would be more than a series of notes jotted down hastily, and given to Professor Hartt as of some possible use to future workers, and much better than nothing at all concerning a large and unknown part of Bahia. The route followed by Mr. Allen from Chique-Chique to the city of Bahia is a mere trail passing through a region covered with catinga forests. These forests crowd so closely on all sides that one may often travel all day without being able to see ten meters beyond the dense wall of vegetation about him. On this route, therefore, especially when one is constantly obliged to press forward in order to reach water and food for his animals, the casual traveler rarely gets an open view of the region through which he is passing, and still less frequently does he have an opportunity to know and keep track of the geologic structure and of the sequence of the rocks. It is not to be wondered at, therefore, that other persons endeavoring to use Mr. Allen's notes have failed to get a correct idea of the geology of the Serra do Tombador and of the relations of its rocks to the surrounding country.

The only other naturalist who crossed this same region and who has written about the geology was Emmanuel Liais, formerly director of the Imperial Astronomical Observatory at Rio de Janeiro. In his *Climats, Géologie, Faune et Géographie Botanique du Brésil* published at Paris in 1872, M. Liais says (pp 180-1 and 189) that he found fossil *Lepidotus* scales and a ganoid tooth, associated with *Paludina* and *Planorbis*, at Engenho on the road from the city of Barra on Rio São Francisco to the city of Bahia. This reported occurrence of Cretaceous fossils has added greatly to the difficulty of understanding the geology of the region as a whole, largely because it was assumed that the *Lepidotus* was from the horizontal beds shown by Mr. Allen to cap the Serra do Tombador.

During the progress of the work done by the writer the Cretaceous fossils, said to have been found by M. Liais, became more and more puzzling. In order to clear up the matter a special trip was finally made to Engenho, and the road followed by him was examined across the Engenho estate. The limestones he mentions were found without difficulty, but the examination of the region made it clear that some mistake had been made with the materials collected by M. Liais, and that the conclusions drawn from them were unwarranted and quite misleading.*

* The rocks at the locality where the fossils are said to have been found are mostly in the form of loose fragments strewn down the southwestern slope of the hill near Rio Salitre. Near and at the base of the hill are out-

A general idea of the structure of the Serra do Tombador can best be had from the accompanying east-west section across the range along the road from Jacobina to Catinga de Moura. The altitude of the crest of the range where this road passes over it is 930 meters (aneroid) above tide level, or 370 meters above the fazenda Santa Cruz at the base of the mountain. The plain to the east, that is between the Serra do Tombador and the Serra de Jacobina, is made up almost entirely of granites, gneisses, schists, and old eruptives. At the fazenda

FIG. 1.



FIG. 1. General east-west section across the Serra do Tombador, the Serra de Jacobina and the valley between.

FIG. 2.



FIG. 2. Looking north-west along the eastern face of the Tombador escarpment. The rounded hills are the granites underlying the Tombador sandstone. Sketch by the author from Genepapo, 20 kilometers south of Jacobina.

Santa Cruz at the eastern base of the range hornblende schists are exposed, and at the fazenda Sitio do Meio, a little further north where the old road starts up the mountain, the rocks are granites. The hills made of these older rocks are mostly low and rounded. Some idea of the general topography, both of the granite hills and of the escarpment so characteristic of the Tombador range, can be had from the accompanying sketches.

In addition to these granitic hills, however, there are a few

crops of lime rocks in place, and these rocks contain abundant remains of recent freshwater shells. But nothing was found, after the most careful search, that even suggested *Lepidotus*, or the rocks in which *Lepidotus* remains have hitherto been found in Brazil. The rocks exposed where these fossils are said to have been found are of two kinds, recent limestones and old, probably Triassic limestones. In the latter the most careful search has been made for fossils at hundreds of exposures, and not a single one has yet been found except certain small oolitic bodies that are probably algæ. One of the following conclusions is inevitable: first, that the *Lepidotus* was found elsewhere, and was credited to this locality by accidental change of label; second, that it was brought from the Cretaceous area north of the Rio São Francisco, or elsewhere, and dropped at this place; or, third, that there was an error in the identification. In any case the evidence afforded by the fossils reported from this locality by M. Liais, excepting *Paludina* and *Planorbis* which are now living in the streams and ponds, must be set aside.

peaks or sharp ridges of quartzite whose beds stand nearly or quite on end. These quartzite peaks and ridges are more or less isolated, and appear to belong to a series of sediments older than either the Jacobina range or the Tombador range.

FIG. 3.



FIG. 3. Serra do Tombador seen from fazenda Santa Cruz. From a sketch by the author.

As suggested by the section and the sketches, the Serra do Tombador is formed by the edges of a resisting series of nearly horizontal beds. These beds the writer has called the Tombador series. They are sandstones and quartzites, and the series is unbroken by intercalated shales. Where the Jacobina-

FIG. 4.

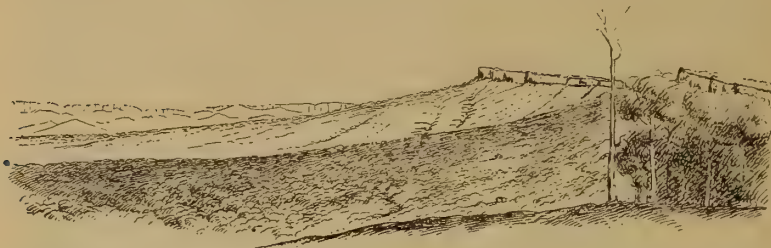


FIG. 4. Looking southwest along the east face of the Serra do Tombador from an elevation of 780 meters, and 30 kilometers west of Jacobina. From a sketch by the author.

Chique Chique road passes the ledge this sandstone series is about a hundred meters thick, and the rocks are rather soft and much jointed, while in color they are pinkish, yellowish, reddish, and gray. They are strongly false-bedded, and on the top of the serra, where large bare surfaces are exposed and the direction of the lamination is well shown, the false dip is toward the north and northwest. Along the face of the bluffs as seen from the old trail, a couple of kilometers north of the

present trail, the false beds are often three or four meters high. The general dip of the beds themselves is gentle and toward the north. At other places the dip is toward the west or northwest, but it is always in the direction of the Salitre valley, of which this range forms the eastern rim. The top of the range is a beautiful open grassy campo, whose surface dips west at an angle of four degrees. Five or six kilometers to the west these grass-covered campos merge into the catinga forests that cover all the rest of the Salitre valley.

Going westward or northwestward down the slope of the range one passes from the Tombador sandstones to a series of whitish flinty beds that the writer has called the Jacuipe flints. These flinty beds seem to overlie the Tombador sandstones conformably. They are well developed in that part of the range locally known as the Serra da Gamelleira and along the southern third of the Tombador range proper. At the fazenda do Poço close to the crest of the serra they have a measured thickness of twenty-seven meters. This, however, is not the total thickness of the flints, for the upper portion of the beds has been removed by denudation.

Thus far no fossils have been found in the flint beds, but at many places the rocks have an oolitic structure. Where they have weathered out on the surface they are often of a light gray color. This gray color is characteristic of the flints over much of the Serra da Gamelleira and over the southern end of the Serra do Tombador, but further north in the latitude of Campo Formoso they are yellowish, brown and red. Following the trail from fazenda do Poço toward Catinga de Moura, the upper limit of the Jacuipe flints is four or five kilometers northwest of the crest of the serra.

Next above the Jacuipe flints and resting conformably upon them is a series of shales that were given the field name of Caboclo shales from their development in the Serra do Caboclo on the west side of the Salitre valley. These shales vary considerably in color and thickness, but the exposure of them at this particular place cannot be regarded as typical or especially good. On this western slope of the Serra do Tombador these shales where exposed on the road are thin-bedded; the lower beds are of a light brown color, while the upper ones are light gray to nearly white with some fine-grained sandstones interbedded with them. The thickness of the shales here is estimated to be between 45 and 90 meters. The same shales are well exposed in the gorge in the lower edge of the town of Ventura, where they are of a yellowish and greenish gray color, jointed and flaggy, and have a gentle western dip. In the bluffs at Ventura these shales strongly resemble the flaggy Cayuga shales at Ithaca, New York. Although the Caboclo shales have been

examined at a great many places and over large areas, no fossils of any kind have yet been found in them.

Next above the Caboclo shales is a series of sandstones which are believed to be the Lavras series of Derby.* The contact between the shales below and the sandstones above is not well exposed at this place, but in the zone of the contact, and especially where the lowest part of the sandstones has been removed by denudation, there are many heavy water-worn boulders scattered over the surface as if they had originally formed part of a basal conglomerate. Some of these boulders are as much as two feet in diameter.

These Lavras sandstones form a series of low hills running parallel with the Tombador range. At this place they are only from twenty to one hundred and fifty meters high, that is above the general level of the plain immediately about them. Though they can be traced for a long distance with the eye, it seems probable that they occasionally disappear altogether.

The road leading to Catinga de Moura from Jacobina was not followed further west than this range of hills formed by the Lavras sandstones. What the next overlying rocks are at this particular place cannot be positively stated from personal observation. A little further toward the northwest on the Engenho estate the rocks are limestones, and it is a matter of common information that the rocks at Catinga de Moura are limestones. Over the surface of the ground near the base of the Lavras beds fragments of the pinkish limestone so common along the Rio Salitre were found. It is, therefore, inferred that the limestone not only overlies the Lavras sandstones, but that it even encircles and passes to the east of the ridges made by those sandstones. Such relations are borne out by observations at other places in the Salitre valley.

The sequence and thicknesses of the various series observed in this section across the Serra do Tombador, as nearly as they could be made out on the Jacobina-Chique Chique road, are estimated as follows.

Salitre limestone (not seen in place)	
Lavras sandstones	46 to 60 meters.
Caboclo shales	45 to 90 “
Jacuipe flints	20 to 30 “
Tombador sandstone	90 “
Granites and gneisses at base about 250 meters visible.	

Further north the sandstones and conglomerates that give character and prominence to the southern extremity of the Tombador range become less conspicuous in the topography. North of the Jacuipe watergap, however, they do not cease to

* O. A. Derby, *Economic Geology*, i, 134-142, Nov.-Dec. 1905.

form the watershed between the Salitre drainage and the drainage into Rio Itapicurú, and into Rio do Poço Comprido. The geology of this watershed was examined by the writer at two other points further north, and the sections as there made out will be of interest in connection with the one already given.

A trail crosses the range between fazenda da Pedra Branca on the east and fazenda da Varzinha on the west side of the watershed. At this place the range no longer forms a bold escarpment; indeed the Tombador sandstones and the rocks that overlie them are all lacking, or are not exposed, up to the Salitre limestones which rest directly or almost directly upon the granites.

It is of interest to note that granites with a few other crystalline rocks extend from the base of this ridge eastward past fazenda Lagoa do Mato to the base of the Jacobina range, and that in this granitic area there are here and there sharp quartzite ridges with their beds standing nearly or quite on end. The fazenda Pedra Branca takes its name from one of these white quartzite hills.

The following section shows the geology as it is exposed on this trail.

FIG. 5.



FIG. 5. Section showing the general geology between fazendas Pedra Branca and Varzinha, a distance of 18 kilometers.

The hill where the road passes over it is less than a hundred meters high. The granites at the base continue half way up the slope; above them is a narrow zone of quartzites and schists, and these are followed by decomposed cherts which cap the ridge. Going down the gentle westward slope of this ridge the cherts are found to overlie and to be part of the Salitre limestone series. The limestones are mostly compact and dark blue. They here have some thin strata of yellowish shale interbedded with them. These limestones mostly have a gentle dip toward the west; but as the mountains near Varzinha are approached the limestones are highly tilted in places.

Five or six kilometers further north the trail from Campo Formoso to Varzinha crosses this same watershed on fazenda Campo Frio. This route furnishes another section from the granite base of the Serra de Jacobina at Campo Formoso to Varzinha, which is on and near the Salitre limestones.

The road from Campo Formoso to Campo Frio is over granite all the way except near the village of Poços, where there is a little quartzite, and a few kilometers further west, where there are some thin patches of basal conglomerate resting directly on the granite. The crest of the watershed between the Salitre drainage and the Itapicurú drainage is only a kilometer or two west of the granite area. This crest is remarkably flat, the soil is of a deep red color, and the abundance of loose flint fragments on both slopes suggest that the flint-bearing beds form the crest of the divide. The topography of the watershed and the appearance of the hills to the north and west all suggest that the limestones with which the flints are associated dip gently toward the Salitre valley. Exposures of bedded limestones a few kilometers further west bear out this idea.

Attention should be called to the fact that although this watershed does not form a bold bit of topography, it has an altitude of 800 meters at the point where the trail crosses it, while the Morro da Mina, one of the prominent peaks of the Serra de Jacobina, has an altitude of 950 meters a. t. In other words, this watershed is a high one in spite of its lack of boldness, and it is the geographic prolongation of the Serra do Tombador in spite of the absence of the Tombador series of rocks.

Further north this watershed swings westward and reaches Rio Salitre at the falls of that stream some thirty-five kilometers south of Joazeiro. The Tombador sandstones again make their appearance somewhere north of the section given above, and thickening up they begin to form the bold topography just east of the cachoeira do Salitre. The falls themselves are made by passing over the Tombador sandstone ledge. West of Rio Salitre they rise into the broken mountainous region and appear again capping the Serra da Cruz and Serra do Mulato as explained in the preceding chapter.*

The character and apparent structural relations of the Tombador beds to those of the Jacobina range suggest that the two ranges may be geologically identical, and that the valley between may be simply a breached anticline. The possibility of such relations was entertained in the early part of the field work, and though it was soon abandoned, it has not been lost sight of. In the total absence of fossils from the rocks of both ranges one is obliged to depend entirely upon lithologic and structural features to settle this question. The chief fact in support of the theory of the identity of the two series is that they both rest upon the old granitic series.

*This Journal, Oct., 1910, pp. 256-263.

Against the theory of the geologic identity of the two ranges are the following facts:

First, the difference in the characters of the rocks themselves. The rocks of the Jacobina range are mostly quartzites of the kinds known in Minas Geraes as itacolumites, while those of the Tombador range are mostly ordinary sandstones. Though the Tombador beds are also sometimes quartzites, the quartzitic nature of the series is not nearly so pronounced or so universal as in the case of the Jacobina range.

Second, the absence from the Tombador range of the soft beds so characteristic of the Jacobina range. These soft beds are talcose schists or slates that break down readily and form the valleys. No such beds have yet been found in the Tombador series. In view of the fact that such soft beds make up about half of the total thickness of the Jacobina series, it seems highly improbable that they would completely disappear in the few kilometers that separate the two ranges from each other.

Conclusions:—The Cretaceous fossils reported by Liai as having been found at fazenda Engenho on the northwestern slopes of the Serra do Tombador are misleading. The fossils, if found where reported, were not in place.

The escarpment of the Tombador range is formed by a thick, horizontal series of false-bedded sandstones and quartzites, that rest unconformably upon a very old series of granites and other crystalline rocks. The sedimentary beds of the Tombador series have thus far yielded no fossils, but they are supposed to be Paleozoic, and are provisionally referred to the Silurian. They are the same as the sandstones that cap the Serra do Mulato and the Serra da Cruz, and they occur over a wide area in the interior of Bahia and along the upper valley of the São Francisco.

Overlying the Tombador beds are the Jacuipe flints, and these are followed by the Lavras sandstones and quartzites, the series of sediments in which the diamonds and carbonados of Bahia are found.

ART. XXXVIII.—*Note on the Age of the Tribes Hill Formation*; by PERCY E. RAYMOND.*

IN a recent paper on the age and relations of the Little Falls dolomite of the Mohawk Valley, Ulrich and Cushing† have separated the upper "fucoidal beds" of Emmons from the non-fossiliferous dolomite below, and have given them the formation-name Tribes Hill. This formation they consider to be of the age of the Lower Beekmantown, and state that it is separated by an unconformity from the underlying dolomite, which they assign to the Ozarkian.

In a paragraph on the age of the Tribes Hill formation, they state: "That the Tribes Hill is younger than any known Ozarkic formation is satisfactorily shown by the presence of *Asaphus* and three or four other trilobites that are wholly unknown in Ozarkic faunas. The same is true of the *Ribeirias*; and the *Dalmanella? wemplei* also is a type that has not been observed below the Canadian. With the exception of *Eccyliomphalus multiseptarius*, the testimony of the gastropods is less positive, very similar, though specifically distinct, forms being found in Ozarkic faunas. The gastropods described by Cleland from the upper chert zone of the Little Falls dolomite at Little Falls are clearly Ozarkic types and hence are not referred to in this paragraph."

The writer has recently restudied the trilobites which occur in the fauna described by Cleland from Fort Hunter, and finds that the *Asaphus canalis?* of that fauna is in no way related to the *Asaphus canalis* of the Beekmantown of the Champlain Valley, but belongs to that division of the Asaphidæ in which the hypostoma is not forked. The trilobite proves to belong to the genus *Asaphellus*, and is redescribed as a species of that genus in a paper now in press. The trilobite described by Weller‡ from Columbia, New Jersey, as *Isotelus canalis* may be the same species.

Another Asaphid with an undivided hypostoma is the "*Asaphus marginalis*" mentioned by Collie§ as occurring in a zone 3,750 feet below the top of the Beekmantown at Bellefonte, and as Ulrich and Cushing state, the fauna occurring with this Asaphid in the Bellefonte section is so similar to that of the Tribes Hill, that the two may safely be correlated.

* Published by permission of the Director of the Geological Survey of Canada.

† Sixth Report of the Director of the Science Division, New York State Museum, 1910, p. 97.

‡ Pal. New Jersey, vol. iii, pl. 3, figs. 5, 6.

§ Bull. Geol. Soc. Am., vol. xiv, p. 407, 1903.

Another Asaphid of the Tribes Hill is the *Asaphus convexus* Cleland = *Bathyrurus levis* Cleland = *Illænurus columbiana* Weller. The narrow axial lobe of the pygidium, as well as the general shape, show that this species is more closely related to *Symphysurus* than to the typical species of *Illænurus*. After untangling the synonymy this species appears to emerge under the name *Symphysurus convexus* (Cleland).

Except for a few species of *Nileus*, information about Asaphids with unforked hypostomas is practically wanting in America, though several species are known. For knowledge of the stratigraphic value of this group, we must, then, turn to Europe, where numerous species are known in Great Britain, France and Scandinavia. In all these countries, *Asaphellus* and *Symphysurus* occur together in the Tremadoc, above the Cambrian and below the range of Asaphids with forked hypostomas. The only *Asaphellus* previously known from the American continent is that described by Matthew* from strata immediately overlying the Cambrian on Cape Breton island. The fauna found there with the *Asaphellus* is a small one, and not closely allied to the one found at Fort Hunter.

Brögger† has pointed out that the Tremadoc (*Euloma-Niobe* fauna) occurs in America, but its exact position and full fauna have never been worked out. Brögger listed a number of species indicating this fauna in Newfoundland and in the conglomerates at Point Levis. *Niobe morrisi* (Billings) was mentioned by him as representing the Asaphids with unforked hypostoma, and to this may be added *Asaphus illænoides* Billings, which is a *Symphysurus*, and *Asaphus goniurus* Billings, a *Megalaspides*. These are, in turn, associated with *Dicelocephalus magnificus* Billings, and, therefore, older than Beekmantown. *Asaphellus* and *Symphysurus* seem, then, to be genera characteristic of the fauna immediately following the Cambrian.

With *Asaphus* removed from the list of trilobites of the fauna of the Tribes Hill the aspect is not very modern, and with the gastropods only specifically distinct from those of the Ozarkian, the whole fauna seems as much Ozarkian as Beekmantownian.

According to Ulrich and Cushing, the stratigraphy shows that the Tribes Hill formation is younger than the Hoyt formation which carries the Saratogan fauna described by Walcott. The fauna of the Hoyt limestone is stated to be similar to that of the Gasconade chert of the Ozarkian of Missouri. The top of the Gasconade chert is from 120–475 feet below the top of

* Bull. Nat. Hist. Soc., New Brunswick, vol. iv, part v, 1902.

† Nyt. Mag. f. Naturvidensk., vol. xxx, 1896, p. 164.

the Ozarkian of Bain and Ulrich's section,* so that there is a place for the Tribes Hill above the Gasconade, if it is to be placed in the Ozarkian instead of the Beekmantown.

All that we now know about the fauna of the Ozarkian is what is given by Ulrich in the paper first referred to in this note, and by Schuchert in "Paleogeography of North America." If the fauna is to be defined as consisting of "Cambrian trilobites and Ordovician gastropods and cephalopods," then the fauna of the Tribes Hill certainly has an Ozarkian aspect, with *Asaphellus*, *Symphysurus*, and *Harrisia* as the common trilobites.

Ottawa, Sept. 1910.

* Bull. U. S. Geol. Survey, No. 267, 1905.

SCIENTIFIC INTELLIGENCE.

I. CHEMISTRY AND PHYSICS.

1. *Metallic Radium*.—Mme. CURIE and A. DEBIERNE have prepared a small quantity of radium in the metallic state. They electrolyzed a solution of pure radium chloride containing about 0.1 g. of the salt, using a platinum anode and a cathode consisting of about 10 g. of mercury. In this way an amalgam of radium was produced, and upon distilling off the mercury in an iron boat contained in a quartz tube filled with carefully purified hydrogen, a minute quantity of what was presumably metallic radium was left behind. At 700° C. the metal began to volatilize and energetically attacked the quartz tube. It has, therefore, a lower boiling point than metallic barium. The metal shows a brilliant white luster, and it melts at 700° . It is altered very rapidly by air, becoming black, probably on account of the formation of nitride. It decomposes water energetically, most of it going into solution, so that the oxide is evidently soluble in water. Since the metal is much more volatile than barium, the authors propose to purify it by sublimation in a vacuum upon a sheet of cold metal.—*Comptes Rendus*, cli, 523. H. L. W.

2. *Separation of Antimony and Tin by Distillation*.—It is well known that arsenic may be conveniently separated from other metals for the purpose of quantitative analysis by Emil Fischer's method of distilling with ferrous chloride and hydrochloric acid. W. PLATO has now found that it is possible to distil over antimonious chloride by the use of a stream of hydrochloric acid gas in a sulphuric acid solution to which phosphoric acid has been added, and which can be heated to a suitable temperature. The phosphoric acid prevents the distillation of stannous chloride at the same time, but after the antimony has been removed it is possible to distil over stannous chloride by elevating the temperature and using hydrobromic acid. For carrying out the operations a special, easily constructed apparatus is described, and test analyses are given which show extremely satisfactory results. The method is recommended for substances containing, besides tin or antimony or both of these, such metals as copper and lead.—*Zeitschr. anorgan. Chem.*, lxviii, 26. H. L. W.

3. *Essentials of Chemistry*; by RUFUS PHILLIPS WILLIAMS. 12mo, pp. 421. Boston, 1910 (Ginn & Company).—This "experimental, descriptive, and theoretical" text-book of elementary chemistry follows a series of briefer works by the same author, which have been extensively used in our schools. In the preface is set forth a list of 21 "innovations and departures from the author's previous works, as well as from current texts." Many of these changes relate to the arrangement of the matter and the

manner of presenting the subject. The book appears to have many excellent features, and it presents a rather extensive course. The illustrations and diagrams are generally good, the experiments are numerous and instructive, and the theory for the most part is clearly presented. However, the author persists in giving incorrect formulas for the common elementary gases, H , O , N , for example, instead of H_2 , O_2 , N_2 , and in this way his "original device of diagrams" for explaining Avogadro's law gives an entirely false impression of the subject, while the simple matter of gaseous combination is at the same time made exceedingly difficult, if not impossible to understand. A good many misprints or misstatements have been noticed. A serious mistake is made in describing an electrolytic apparatus for manufacturing caustic soda, where it is stated that the sodium chloride is *fused* in contact with a layer of *mercury*, an impossible condition of things on account of the temperatures at which mercury boils and salt fuses.

H. L. W.

4. *A Text-Book of Organic Chemistry*; by WILLIAM A. NOYES. 12mo, pp. 537. New York, 1910 (Henry Holt & Co.).—This is a revised, second edition, of the work which appeared about seven years ago. It is so well known to the chemical public that it requires no special comment, except that a few changes and additions have been made, most of which were prepared for the German edition, and that the short final chapter on compounds of interest in physiology and pathology has been re-written.

H. L. W.

5. *Allen's Commercial Organic Analysis*, Fourth edition; edited by W. A. DAVIS and SAMUEL S. SADTLER. Vol. III, 8vo, pp. 635. Philadelphia, 1910 (P. Blakiston's Son & Co.).—This important work, which is being entirely re-written in the present edition, will consist of eight volumes when complete. The third volume, under consideration, treats of the hydrocarbons, including olefines, acetylenes and tars, bitumens, including the various petroleum products and the coal-tar hydrocarbons, naphthaline and its derivatives, anthracene and its associates, phenols, aromatic acids, gallic acid and its allies, phthalic acid and phthalins, and modern explosives.

H. L. W.

6. *Analytical Chemistry. Volume II, Quantitative Analysis*; by F. P. TREADWELL. Translated by WILLIAM T. HALL. 8vo, pp. 785. New York, 1910 (John Wiley & Sons).—This excellent text-book, which now appears in the second American edition, has been compared with the fourth German edition. The total issue of the book, six thousand copies, indicates that it is very extensively used in the United States.

H. L. W.

7. *Ozone and Ultra-Violet Light*.—It has been supposed that ozone is produced in the upper regions of the atmosphere by means of sunlight, and the ionizing effect of this light—mainly coming from short wave lengths—has been supposed to influence the transmission of electrical waves. E. v. BAHR concludes that since the ozonizing rays are strongly absorbed by air the ozoniz-

ing effect must be limited to the extreme upper regions of the atmosphere; but in these regions the deozone effect of sunlight is also very strong, and it does not seem probable that a noticeable quantity of ozone exists there.—*Ann. der Physik*, No. 13, pp. 598–606. J. T.

8. *Influence of Pressure upon the Absorption of Ultra-Red Radiation in Gases*.—E. v. BAHR concludes that an increase of pressure results in both a qualitative and quantitative change of the absorption of oxide of nitrogen; and that the qualitative change of the absorption is important only with low pressures. The absorption band at very low pressures consists of fine lines, which, however, quickly broaden with increase of pressure, and run together at a pressure of 50^{mm} .—*Ann. der Physik*, No. 13, pp. 585–597. J. T.

9. *Metallic Radium*.—MADAME CURIE describes her method of obtaining metallic radium. The principle of the method consisted in preparing an amalgam of mercury and metallic barium, and a process of distillation to get rid of the mercury. At the end of the process, a brilliant white metal was obtained which melted at approximately 700°C . It adhered strongly to iron, altered very rapidly in air, blackening immediately. Particles of the metal put upon paper produce a blackening analogous to a burning effect. In contact with water the metal is energetically decomposed.—*Comptes Rendus*, Sept. 5, 1910. See also on p. 347. J. T.

10. *Wireless Telegraphy*.—MARCONI states that messages have been transmitted between Clifden, Ireland, and Glen Bay, Canada, in daylight. The distance is 3500 miles. A pole was used for the support of the aerial wire on the vessel. The greatest previous distance at sea was 1750 miles.—*Nature*, Sept. 29, 1910. J. T.

11. *A New Alloy*.—The chief chemist of the works of Messrs. Vickers Sons & Maxim announces the discovery of an alloy, which he calls Duralumin. It is slightly heavier than aluminium, it is strong as steel, and can be rolled, drawn, stamped, extended or forged at suitable temperatures. It is less corrodable than other alloys of aluminium and is one-third the weight of brass.—*Nature*, Sept. 8, 1910. J. T.

12. *Handbuch der Spectroscopie*;* by H. KAYSER. Vol. V. Pp. vi, 853, with 2 plates and 3 figures. Leipzig, 1910 (S. Hirzel).—This volume contains *all* the reliable data pertaining to the spectra of fifty elements. The subject matter is arranged alphabetically with respect to the chemical symbols of the elements and hence the list ends with nitrogen. Such rare or hypothetical elements as coronium, davyum, demonium, radium emanation, holmium, incognitum and ionium of Crookes are included. In addition, the spectra of air, lightning, the aurora borealis and meteors, as well as the spectroscopic phenomena associated with the Bessemer process, are discussed. The remainder of the elements will be treated in a similar, exhaustive manner in volume VI.

* See this Journal, vol. xxv, p. 522, 1908.

The bibliography of the (alphabetically) first elements is complete through the year 1908 and it has been carried right up to date for the last elements. Very great care has, also, been taken to avoid errors in the tables of wave lengths. Consequently, volumes V and VI will be of great value to a much wider circle of readers than the preceding volumes, inasmuch as the bibliographic lists and the numerical tables will appeal to any investigator in any subject who needs such data, whereas the first four volumes deal with material which is of interest chiefly to workers in the comparatively special field of spectroscopy. Judged by this standard, volume V is by far the most important work on the subject extant.

H. S. U.

13. *Physical Measurements*; by A. W. DUFF and A. W. EWELL. Second edition. Pp. xi, 256. Philadelphia, 1910 (P. Blakiston's Sons & Co.).—This is the second edition of a laboratory manual previously reviewed in this Journal (June, 1909). It retains the many excellent qualities of the first edition, and has been somewhat enlarged. The typography and diagrams have been distinctly improved.

H. A. B.

14. *Der Lichtbogen als Wechselstromerzeuger*; von WILLY WAGNER. Pp. vi, 119. Leipzig, 1910 (S. Hirzel).—This book gives a connected account of the work which has been done during the last ten years upon the electrical oscillations set up when an arc is shunted by capacity and inductance. The theory of the phenomenon is discussed and the applications to wireless telegraphy and telephony are described. Considerable attention is given to the author's own work on metallic arcs.

H. A. B.

II. GEOLOGY AND MINERALOGY.

1. *Diverse Effects of Glaciation on the Cretaceous Clays*; by A. C. HAWKINS. (Communicated.)—Heinrich Ries, in his recent book* dealing with clay deposits, describes types of deformation in clays, as follows: "Beds of clay and shale sometimes show folds or undulations.—Many clay deposits in the Northern States show a local folding caused by the shoving action of the ice-sheet during the glacial period. Such folds, however, are of minor account, and affect only a few beds.—Where a bed is not sufficiently elastic to bend under pressure, it breaks, and if, at the same time, the beds on opposite sides of the break slip past each other, faulting is said to occur.—Every bed terminates abruptly at the fault-plane, its continuation on the other side being at a higher or lower level. Displacements of this type are somewhat rare in surface clays, and if occurring, the throw is not apt to exceed a few feet."

An excellent case of each of the foregoing types has been brought to light by recent excavations in the Cretaceous clays of

* Heinrich Ries: "Clays, their Occurrence, Properties, and Uses," pp. 28-30.

the Perth Amboy district in New Jersey. In these exposures, the structures were so admirably shown that the writer has thought it worth while to make a note of the occurrence.

When first met with in the field, these dislocations in the clays were thought to be due to glacial pressure; and we have been strengthened in this opinion by the receipt of certain letters from Dr. H. B. Kümmel, State Geologist of New Jersey, who says in part: "I have yours of July 3d and also the photograph which you so kindly sent me. It certainly shows a very good example of a local fold in the upper part of the clay, caused by the ice

FIG. 1.



FIG. 1. Folding in Cretaceous clays resulting from glacial pressure.

movement." "The faults in the clay bed at Maurer are, in my opinion, probably due to disturbances during the glacial period, as I have observed similar faults in a number of pits in Middlesex County where the glacial drift overlies the Cretaceous, whereas in non-glacial portions of the state faults in the Cretaceous are very rare."

Both of these exposures were made in the process of mining brick and fire clays by the usual open cut method. The faulting (fig. 2), which occurred at Maurer, Middlesex Co., took place in dark and light gray, plastic brick clays, in the upper part of the so-called Woodbridge clay horizon. The folding (fig. 1), seen two miles farther west, near Woodbridge, in the same county,

took place in clays of a slightly lower horizon in the same series, very similar in color, though more thinly laminated and sandy than the higher beds.

The anticlinal folding (fig. 1) was exposed in a pit now being worked near the road leading from Metuchen to Woodbridge, this road being a continuation of Main street (Woodbridge) and the location about half a mile west of the latter town. The floor of the pit is about 25 feet below the level of the road at this point, and on its south side. A beautiful 15 foot anticline in the clays on the west side of the pit was formerly conspicuous,

FIG. 2.



FIG. 2. Faulting in Cretaceous clays resulting from glacial pressure.

but has since slumped down. The present smaller fold is in the south wall, and at the time when the photograph was taken was at the principal point of attack on the clay deposit. To right and left of the fold were thinly laminated clays in alternating dark and light layers, forced up into close plications, much like the smaller plications in the pre-Cambrian gneisses. Under the crest of the main anticline there was a noticeable thickening of one layer, evidently due to the squeezing up of the bed into the space under the arch, as the latter was raised. The apparent unconformity (disconformity) in the wall near the floor of the pit was probably due to irregularity of deposition.

The second exposure (fig. 2) was made in the process of removing a clay deposit in a small hill, just east of the C. R. R. tracks

(Long Branch Division), and about 200 yards south of the station at Maurer, Middlesex Co., in a pit known as Dunnigan's pit. The excavation, having proceeded at a level slightly below the railroad for some 200 feet into the hill, developed a vertical wall of clay, in which was shown the faulting herein described. This wall or quarry face was 150 feet long and 7 to 10 feet high, and showed, as it progressed, five or six separate faults, each of which slightly dislocated the layers of the deposit.

The clays here, as elsewhere in this region, are nearly horizontal, having a dip of only 35 to 60 ft. per mile toward the southeast. They form part of a coastal plain deposit, on which, as the prominent black lignite seam in the section shows us (see fig. 1), vegetation grew for a certain period, to be overwhelmed again after a time by the clay deposition. It will be noted that the layers of clay immediately above and below the lignite are darker in color than those farther away from it, in this case indicating a larger portion of carbonaceous matter in the former. The clay layer below the lignite seam shows numerous woody lignite fibers, extending downward in a vertical direction. These without doubt represent the roots of the earliest vegetation which furnished the lignite. Seams of this kind are very uncommon in the pits of Middlesex County, though isolated logs and stumps of lignite are common.

It will be noted that but for the presence of the black seam and the darker clays surrounding it, there would be no well-marked evidence of any faulting, because of similarity in the color and texture of the beds. Even a very close scrutiny of the clay wall failed to show any noticeable crevice along the fault plane which subsequent pressure had not completely closed. Even the fault scarp, which would normally appear at the top, was completely removed by the glacial action, and the boulder clay, which was later deposited above, of course can show no evidences of the faulting, of which it is entirely independent.

The several faults exposed were all parallel in strike, which was roughly N-E-S-W, at right angles to the movement of the ice, which is suggestive. Moreover, the downthrow, which varied from four inches in the smallest one to about two feet in the one here figured, was in every case toward the southeast, away from the source of pressure.

Some interesting geological speculation might be based on these phenomena. For example, why did folding take place in one case and faulting in another? Why are not phenomena of this kind more common in those clay deposits which lie within the terminal moraine? Was the local deformation due to excessive thickness of the ice, or to local weakness in the clay, and if so, may it not have been a similar local variation in strength that caused folding in one case and faulting elsewhere?

Mineralogical Department, Princeton University.

2. *The Middle Devonian of Ohio*; by CLINTON R. STAUFFER. Geol. Surv. Ohio, Bull. 10, 1910, 204 pages and 17 plates.—The author here presents in detail an excellent and up-to-date account of the Middle Devonian stratigraphy and faunas scattered along the eastern and northern sides of the Cincinnati arch. At the base is the Columbus limestone, 105 feet thick in central Ohio, thinning to 61 feet at Sandusky and to 55 feet west of Toledo. Over it lies the Delaware limestone, 36 feet thick, followed by the Olentangy shale of 31 feet thickness. The last two formations cannot be recognized as such in the northwestern corner of Ohio, and here the Columbus limestone is overlain by the Traverse formation seemingly not over 47 feet in thickness.

The Columbus coral reef fauna, also rich in brachiopods and especially in gastropods, is very large and has 337 species. The Delaware has 141 and the Olentangy 52 forms. The deposits are continuous in deposition, proven by the fact that 75 species of the Columbus fauna go into the Delaware, while a little more than one-half of the Olentangy fauna is derived from below. The Columbus fauna correlates well with the Onondaga of the New York standard section, while the Olentangy shale agrees best with the lower Hamilton; the Delaware, on account of continuing the limestone facies of the Columbus, retains much of its fauna but the new migrants point to Marcellus time. The Traverse fauna consists of 128 species, is decidedly Hamilton in aspect and links directly with the development as exposed about Thedford in western Ontario. The interrelation of the Ohio Basin fauna with those of New York and the Indiana and Michigan basins is fully discussed, and the areas of faunal spread are shown on two paleogeographic maps. C. S.

3. *Paleoniscid Fishes from the Albert Shales of New Brunswick*; by LAWRENCE M. LAMBE. Canada, Geol. Surv. Branch, Memoir No. 3, pages 35, plates 11, 1910.—From the petroleum and sulphate of ammonia-bearing dark shales of New Brunswick the author here describes at length five species in three genera of ganoid fishes. The Albert shales are held to be synchronous with the Carboniferous Sandstone series of Mid and West Lothian, Scotland. The latter are considered by the British Survey "to form the base of the Carboniferous system in that country." C. S.

4. *Outlines of Geologic History with especial reference to North America*. Symposium organized by BAILEY WILLIS: Compilation edited by ROLLIN D. SALISBURY. Pp. 306, 1910 (University of Chicago Press).—The above title is the one of the title page but the book will be known as "Outlines of Geologic History." Few will recognize in either of these titles the symposium on Correlation organized by Willis and presented before Section E of the 1908 meeting of the American Association for the Advancement of Science at Baltimore. The various essays of this symposium were with one exception printed in the Journal of Geology during last year and all are here reprinted in more

convenient form. The printing and appearance of the book is good and the volume is well worth the money asked for it (\$1.50 net).

There are 14 essays, describing the historical geology of North America, by Van Hise, Adams, Walcott, Grabau, Weller, Girty, David White, Williston, Stanton, Knowlton, Dall, Arnold, Osborn and Salisbury. Willis presents 15 paleogeographic maps with short descriptions of each one. The last essay of the book is by Chamberlin on "Diastrophism as the Ultimate Basis of Correlation," and Macdougall has one on "Origination of Self-generating Matter and the Influence of Aridity upon its Evolutionary Development."

Of new matter there is on page 37 a short note by Walcott in regard to the range of *Holmia* in the Cordilleran region; on page 85 an eighteen-line note by Grabau in regard to the character of the St. Peter sandstone in reply to Calvin's doubts as to the aeolian origin of this formation; and on page 125 a three-line note by Girty. Chapter 13 by Osborn did not appear in the *Journal of Geology* and is entitled "Correlation of the Cenozoic through its Mammalian Life." c. s.

5. *Paleontology and the Recapitulation Theory*; by E. R. CUMINGS. Proc. Indiana Acad. Science, Meeting of 1909, pages 36.—Professor Cumings here answers the critique of the recapitulation theory or biogenetic law by Montgomery in his "An Analysis of Racial Descent." His conclusions are as follows:—

"Paleontologists almost universally accept the theory of recapitulation. Its chief critics have been embryologists. The reason for the difference in attitude is probably to be sought in the fact that the former ordinarily compare epembryonic stages with adult characters of geologically older species, while the latter too often compare embryonic stages with the adult stages of existing species. It is also to be noted that in recapitulation we have to do with morphological and not with physiological characters, and that the row of cells from the egg to the adult may be morphologically the same in two organisms while being at the same time physiologically different. Until it can be shown that two organisms morphologically different in the adult must of necessity be morphologically different at all stages, the argument of Montgomery, Hurst and others proves nothing.

"In the Cephalopoda, Pelecypoda, Gastropoda, Brachiopoda, Trilobita, Bryozoa, Graptolites, Echinoderms and Corals, examples are pointed out in which there is clear and unmistakable evidence of recapitulation. In most of these cases it is the epembryonic and not the embryonic stages that are the basis of comparison."

The paper also cites the more important literature treating of recapitulation. c. s.

6. *Ordovician Stromatoporoids*, paper No. 7; by W. A. PARKS. Univ. of Toronto Studies, Geological Series, 1910, pp. 52, pls. 21-25.—Here are described 19 forms of American Ordo-

vician stromatoporoids in 4 genera ; 1 genus and 9 species or varieties are new. Their study has proven to be very time-consuming due to the poor preservation of this material in the Ordovician.

C. S.

7. *Fossil Plants*: A text-book for Students of Botany and Geology ; by A. C. SEWARD. Vol. ii, small 8vo, pp. viii, 624, with frontispiece and 376 illustrations in text. Cambridge, 1910 (The University Press).—It is now nearly twelve years since the publication of the introduction to the modern methods of fossil plant study constituted by vol. i of Professor Seward's invaluable work. With its six most instructive preliminary chapters, followed by the consideration of the thallophyta, bryophyta and equisetales, that volume virtually marked a new era in paleobotanic texts, and was indeed very soon followed by those philosophic "Studies in Fossil Botany" by Scott, by the admirable "Éléments de Paléobotanique" of Zeiller and by Polonić's "Pflanzen-paleontologie," while the progress of the preceding decennial had been so well recorded in that most usable of manuals, Solms' *Fossil Botany*.

Though with each year we looked forward to the appearance of the second volume of *Fossil Plants*, it was perhaps as much a necessity as "a Fabian policy" to delay its appearance till now ; for progress in Paleobotany has been so rapid in the past twelve years that, as Professor Seward says, he has "decided to take the consequences of having embarked on a too ambitious plan of treatment and to preserve the uniformity of proportion by reserving the seed-bearing plants (with geographic distribution) for a third volume." Meantime one can scarce avoid taking very seriously the author's promise of "as little delay as possible in its preparation" ; for its field has become a notable one.

In the volume before us the subjects treated are, then, the Sphenophyllales (continued), Psilotales, Lycopods, Sigillaria, Stigmaria, and the now so much realigned Filicales, exclusive of the seed-bearing section or the Pteridosperms, or "pseudo-ferns." A peculiarly usable feature of the work is the introduction of these major divisions by the illustration and description of suggestive types from existing floras. This is a great book, and its perusal clearly shows that we are only beginning to recognize the significance of the fact that in Paleobotany more than in either vertebrate or invertebrate paleontology, we have the immense advantage of ever and anon interpreting outer morphology in the light of full details of histologic structure.

As really pertaining to discussion that will more properly fall within the scope of Professor Seward's third volume, it may be scarcely fair to single out an error in relation on page 396, where *Crossotheca* is spoken of as a type of frond,— "always regarded as Marattiaceous until Kidston proved it to be the microsporophyll of *Lyginodendron*." In the first place an adumbration of the fact that much of the fern foliage of the paleozoic must be in some way anomalous occurs in the work of Stur. Nearly

thirty years ago he fairly wrote that, "The discovery that in the Culm and Carbon fertile ferns were really abundant . . . brings me to a further observation. Since great numbers of sterile fronds from these horizons known under the names of *Neuropteris*, *Alethopteris*, *Odontopteris*, *Dictyopteris*, etc., and thus far held to be ferns, have never been found fertile despite the diligent search of many investigators, such forms cannot be ferns . . . are *Nichtfarne*."

And specifically, quite five years before Kidston's determination, it was stated in this Journal (June, 1901, pp. 433-435) that in view of the Marattiaceous form of the fertile frond of *Cycadeoidea*, "an extraordinary interest will henceforth attach itself to the fructifications of the *Calymmatothecan* and *Scolecop-teran* type, as well as to the possibility of accompanying *Macrosporophylls*." Indeed *Crossotheca* itself was mentioned in this connection, and it was concluded probable that the dimorphism of various paleozoic plants usually referred to the ferns, "is intimately connected with forms of heterospory and the acquiring of the seed habit. . . ." Interpretation of evidence could scarcely have gone further or been more obvious, and it should not be necessary to lose sight of historical perspective while enforcing the all-important lesson of the "futility of dogmatic assertions" based on the outer form of ferns, or may one add, of *Angiosperms*.

G. R. W.

8. *Canada, Department of Mines*.—Recently received publications are noted in the following list:

GEOLOGICAL SURVEY BRANCH.—Summary Report of the Geological Survey Branch for the Calendar year 1909. Pp. viii, 307. No. 1120.

A Geological Reconnaissance of the Region traversed by the National Transcontinental Railway between Lake Nipigon and Clay Lake, Ontario; by W. H. COLLINS. Pp. 67, with 2 plates and one diagram. No. 1059.

Memoir No. 7. Geology of St. Bruno Mountain, Province of Quebec; by JOHN A. DRESSER. Pp. 33 with 3 plates and 2 maps. No. 1077.

A Reconnaissance across the Mackenzie Mountains on the Pelly, Ross, and Gravel Rivers, Yukon, and North West Territories. By JOSEPH KEELE. Pp. 54, with 19 plates and one map. No. 1097.

Memoir No. 3. Contributions to Canadian Palæontology. Volume III (quarto). Part V.—Palæoniscid Fishes from the Albert Shales of New Brunswick. By LAWRENCE M. LAMBE. Pp. 69, with 11 plates. No. 1109. See p. 354.

MINES BRANCH.—Summary Report of the Mines Branch for the Calendar year ending December 31, 1909. Pp. ix, 181, with 4 plates. No. 63.

Annual Report of the Division of Mineral Resources and Statistics on the Mineral Production of Canada during the Calendar years 1907 and 1908. JOHN McLEISH, Chief of the Division of Mineral Resources and Statistics. Pp. 286. No. 58.

Bulletin No. 2. Iron Ore Deposits of the Bristol Mine, Pontiac County, Que. Magnetometric Survey, etc.; by E. LINDEMAN. Magnetic Concentration of Ores; by GEO. C. MACKENZIE. Pp. 15, with 2 plates and 2 figures.

Bulletin No. 3. Recent Advances in the construction of Electric Furnaces for the production of Pig Iron, Steel, and Zinc; by EUGENE HAANEL. Pp. 76, with one plate and 17 figures. No. 68.

Report of Analyses of Ores, Non-Metallic Minerals, Fuels, etc. made in the Chemical Laboratories during the years 1906, 1907, 1908, arranged by F. G. WAIT. Pp. 126 with 2 plates. No. 59.

Map of the Porcupine Gold Area, districts of Sudbury and Nipissing, Ontario; by A. G. Burrows, geologist, and W. R. Rogers, topographer.

9. *Barbierite*, a Monoclinic Soda Feldspar; by WALDEMAR T. SCHALLER. (Communicated.)—The existence of a monoclinic dimorphous form of albite, isomorphous with orthoclase, has long been suggested, but the presence of soda in orthoclase analyses has generally been otherwise explained. In such cases the presence of albite or anorthoclase has generally been suggested as the explanation of the soda present. In a recent paper by Barbier and Prost,* analyses are given of feldspars in which the cleavage angle varies but a few minutes from 90° and in which soda is present in molecularly greater amount than the potash. The maximum soda content is reached in a feldspar from Kragerö, Norway, in which only 1.15 per cent K_2O was found.

Examination under the microscope showed that (with one exception) albite was not present, and the existence of a monoclinic soda feldspar isomorphous with orthoclase must be admitted. I propose to call this particular monoclinic soda feldspar *barbierite*, in honor of Prof. Ph. Barbier, of the University of Lyons, France, who has recently published, in addition to the paper above cited, another one on the feldspar group, in which he gives a definite chemical difference between orthoclase and microcline.† Further analyses of soda-rich orthoclases are given by him in a later paper.‡ The feldspar from Kragerö is nearly pure *barbierite*.

In a very recent number of the *Neues Jahrbuch für Mineralogie*, etc., Angel gives a description of a soda-bearing monoclinic sanidine,§ which contains 4.92 per cent Na_2O and 6.73 K_2O . The cleavage angle $(001) : (010)$ is $90^\circ 01'$ and the extinction on (001) is parallel. The feldspar is monoclinic and consists approximately of equal parts of the isomorphous orthoclase and *barbierite*. In this paper are given several references to earlier ones on

* Barbier, and Prost, A., Sur l'existence d'un feldspath sodique monoclinique, isomorphe de l'orthose, Bull. Soc. Chim., III, p. 894, 1908.

† Barbier, Ph., Recherches sur la composition chimique des feldspaths potassiques, Bull. Soc. Franc. minéral., vol. xxxi, p. 152, 1908.

‡ Barbier, Ph. and Gonnard, F., Analyses de quelques feldspaths français. Bull. Soc. Franc. minéral., vol. xxxiii, p. 81.

§ Angel, Franz, Über einen Natronsanidin von Mitrowitz, Neues Jahrb. Mineral. Geol. u. Pal., Beilage-Band, xxx, 254, 1910.

feldspars which undoubtedly contain barbierite in isomorphous admixture. See also, for example, the orthoclase described by Ford.*

Chemical Laboratory, U. S. Geological Survey.

10. *Brief notices of some recently described Minerals* (see p. 90, vol. xxx).—WILTSHIREITE is a new species from that most prolific locality, the Binnenthal in Switzerland; it is described by W. J. Lewis. It occurs in small crystals grouped in parallel position and associated with sartorite in a cavity in the well-known dolomite of the region. The color is tin-white with occasionally a russet tarnish. The material thus far available is too scanty for a determination of the chemical composition, but it is regarded as probably a sulpharsenite of lead. The crystals are monoclinic and are referred to the axes: $a:b:c = 1.587:1:1.070$; $\beta = 79^\circ 16'$. The habit is prismatic, the crystals being elongated in the vertical direction, in which zone the faces are strongly striated. The hemidomes are, however, smooth and bright and the same is true of the hemipyramids. The mineral is named in honor of the late Rev. Thomas Wiltshire, at one time Professor of Mineralogy in Kings College, London.—*Phil. Mag.*, September, 1910, p. 474.

MINGUETITE is a hydrated iron silicate described by A. Lacroix and regarded by him as intermediate between stilpnomelane and lepidomelane; it had been called biotite. It forms masses of a greenish black color consisting of confused aggregates of small brittle plates; these are opaque except when very thin and in that case they show a dislocated black cross of negative character. The specific gravity is 2.86 and the composition is given by the analysis (by Pisani):

SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	FeO	MgO	CaO	Na ₂ O	K ₂ O	H ₂ O
43.65	5.22	18.80	19.00	3.22	0.94	0.66	3.00	6.00 = 100.49

From the above the formula calculated is $17\text{SiO}_2 \cdot 4\text{Fe}_2\text{O}_3 \cdot 8\text{FeO} \cdot \text{K}_2\text{O} \cdot 8\text{H}_2\text{O}$. A small part of the ferric iron is replaced by aluminium. The name given refers to the mine, Minguet, at which it was found; this is situated in the Segré region, Maine et Loire, France.—*Bull. Soc. Franç. Min.*, xxxiii, 270.

STELLERITE is a zeolitic mineral allied to heulandite and stilbite, described by J. Morozewicz from a diabase tuff on one of the Commander islands in Bering Sea. It occurs in crystals which are orthorhombic both in form and optically; these are tabular in habit, resembling stilbite, and show perfect cleavage parallel to b . Hardness 3.5–4, specific gravity 2.12. Analysis gave:

	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	CaO	Na ₂ O	H ₂ O
$\frac{2}{2}$	59.23	14.41	0.22	8.23	tr.	18.15 = 100.24

From this the formula obtained is $\text{CaAl}_2\text{Si}_7\text{O}_{18} \cdot 7\text{H}_2\text{O}$; this is

* On Orthoclase Twins of Unusual Habit, this Journal, xxvi, p. 149, 1908.

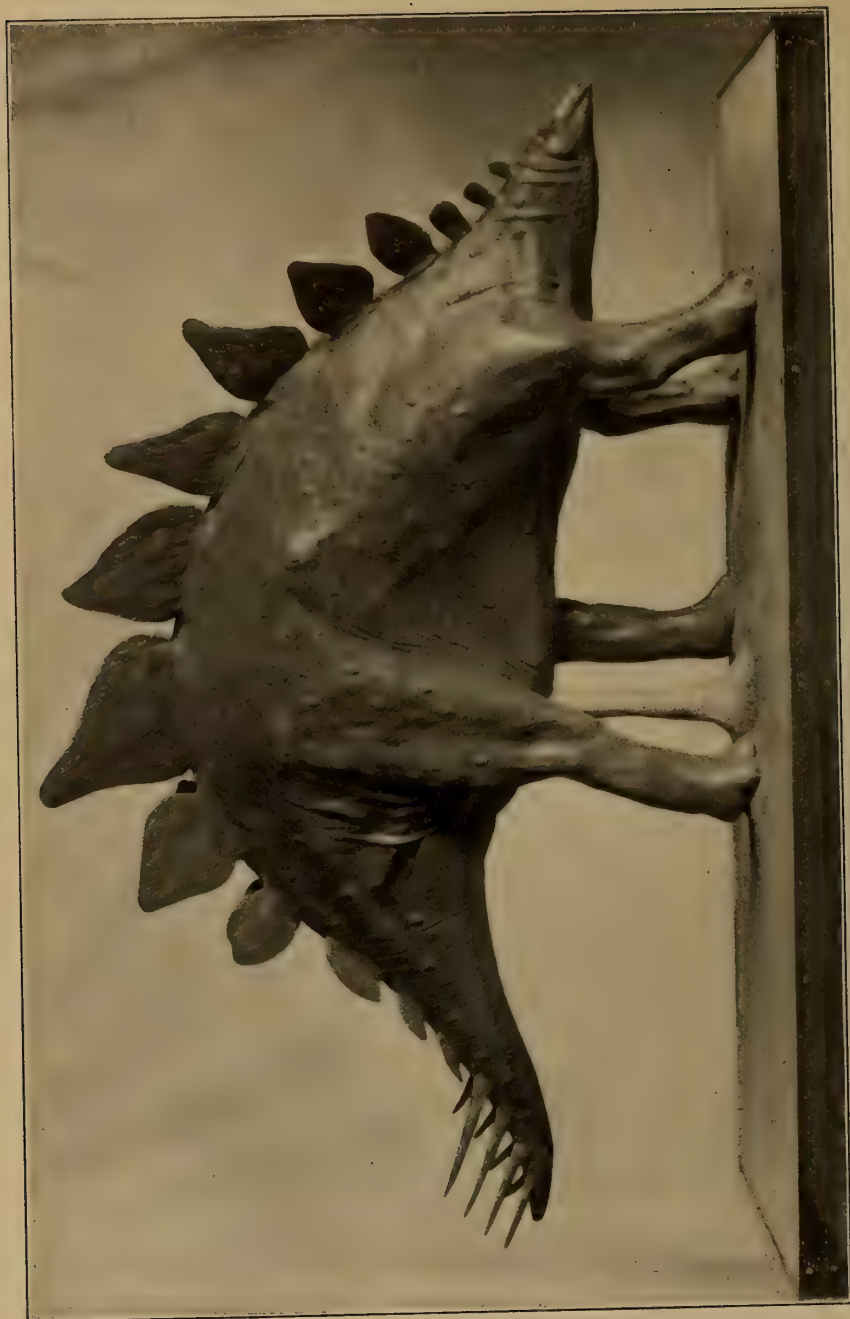
peculiar in its seven molecules of water.—*Anz. Akad. Wiss. Krakau*, 1909, p. 344; quoted in *Jahrb. Min.*, ii, 25 ref., 1910.

TURANITE and ALAITE are two new vanadium minerals, announced but not as yet fully described by K. Nenadkewitsch. They come from the mines of Tjuja-majun in the foothills of the Alai mountains in Central Asia, and occur in a coarse granular calcite. Turanite forms compact aggregates, reniform and radiated in structure, and is stated to have the composition $5\text{CuO} \cdot \text{V}_2\text{O}_6 \cdot 2\text{H}_2\text{O}$. Alaite is a decomposition product having a dark red color and silky luster; to it the formula $\text{V}_2\text{O}_6 \cdot \text{H}_2\text{O}$ is assigned. Analyses and full descriptions follow later.—*Bull. Acad. St. Pet.*, 185, 1909, noticed in *Jahrb. Min.*, i, 193 ref., 1910.

11. *Les Roches alcalines de Tahiti*; par A. LACROIX. *Bull. de la Soc. Géol. de France*, 4 ser., x, p. 91, 1910.—In this article the writer describes a series of alkaline rocks from the valley of the Papenoo River in Tahiti. The massive granular types include nephelite-syenite, monzonite containing nephelite, theralite, and essexitic gabbro. The calculation of the norm from the chemical analysis of the latter shows it to fill an unnamed sub-rang in the quantitative classification for which the term *papenoose* is proposed. Of attendant dike rocks, tinguaïtes, camptonites, monchiquites, and microgabbros are described, while the effusives comprise phonolites, hauynophyres, basalts, and picrites. Of most of these analyses are given. From this it will be seen that the series presents a well-defined clan of typical alkalic character. Regarding the occurrences, areas, and geological relations not much has, as yet, been learned, owing to the denseness of the vegetal covering.

Although the finding of new occurrences of alkalic groups of this kind is always interesting from several points of view, it is doubly so in this case. The discovery of rocks of continental types in this part of Polynesia in mid-Pacific is of wide geological importance. Moreover, it has been claimed by Harker, Becké, and others that the igneous rocks of the Pacific basin are of sub-alkalic (alkalicalcic) nature, those not in this hemisphere generally speaking alkalic. With typical alkalic groups, or members, turning up in Hawaii, Easter Island, Clipperton atoll, Samoa, Fiji, and now at Tahiti, it would be well, as Lacroix remarks, to use the terms of alkalic and alkalicalcic (sub-alkalic) groups, and to avoid the geographical designations of Atlantic and Pacific, until further research has shown that the generalizations, on which these terms are based, are really well founded. It begins to appear to the reviewer as if the rocks of the mid-Pacific might belong to an alkalic petrographical province, and the alkalicalcic to a broad circumferential belt related to the edges of the continental platforms.

L. V. P.



Model of *Stegosaurus ungulatus* based upon the mounted skeleton. Right side. Modeled by R. S. Lull.

THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

ART. XXXIX. — *Stegosaurus unguatus* Marsh, recently mounted at the Peabody Museum of Yale University; by RICHARD S. LULL. (With Plate II.)

[Contributions from the Paleontological Laboratory of Peabody Museum, Yale University, New Haven, Conn., U. S. A.]

CONTENTS :

- Introductory.
- I. The specimen.
- II. The skeleton.
- III. Armament.
- IV. Central nervous system.
- V. Restoration in the flesh.
- VI. Measurements.
- VII. Life conditions and relationships.

THERE has recently been mounted at Yale University an almost perfect example of the armored dinosaur *Stegosaurus*, in many respects the most grotesque reptile the world ever saw. The interest lies not only in this, but in the fact that, while well known in literature owing to the masterly restoration upon paper by Professor Othniel C. Marsh, this reconstruction constitutes the first actual assembling of the bones in their proper relationships with, as usual, a somewhat different result from the generally accepted conception of the animal.

The genus *Stegosaurus* was first described by Professor Marsh in this Journal in 1877, the description being based upon the skeleton now mounted. Repeated articles by Marsh added to our knowledge of the creature until, in 1891, the first attempt was made to restore the animal on paper with the wonderfully accurate results attained by Marsh in so many similar drawings. Some errors naturally creep in when one is working entirely in one plane of space. These the actual mounting of the skeleton bone by bone alone can rectify.

AM. JOUR. SCI.—FOURTH SERIES, VOL. XXX, No. 180.—DECEMBER, 1910.

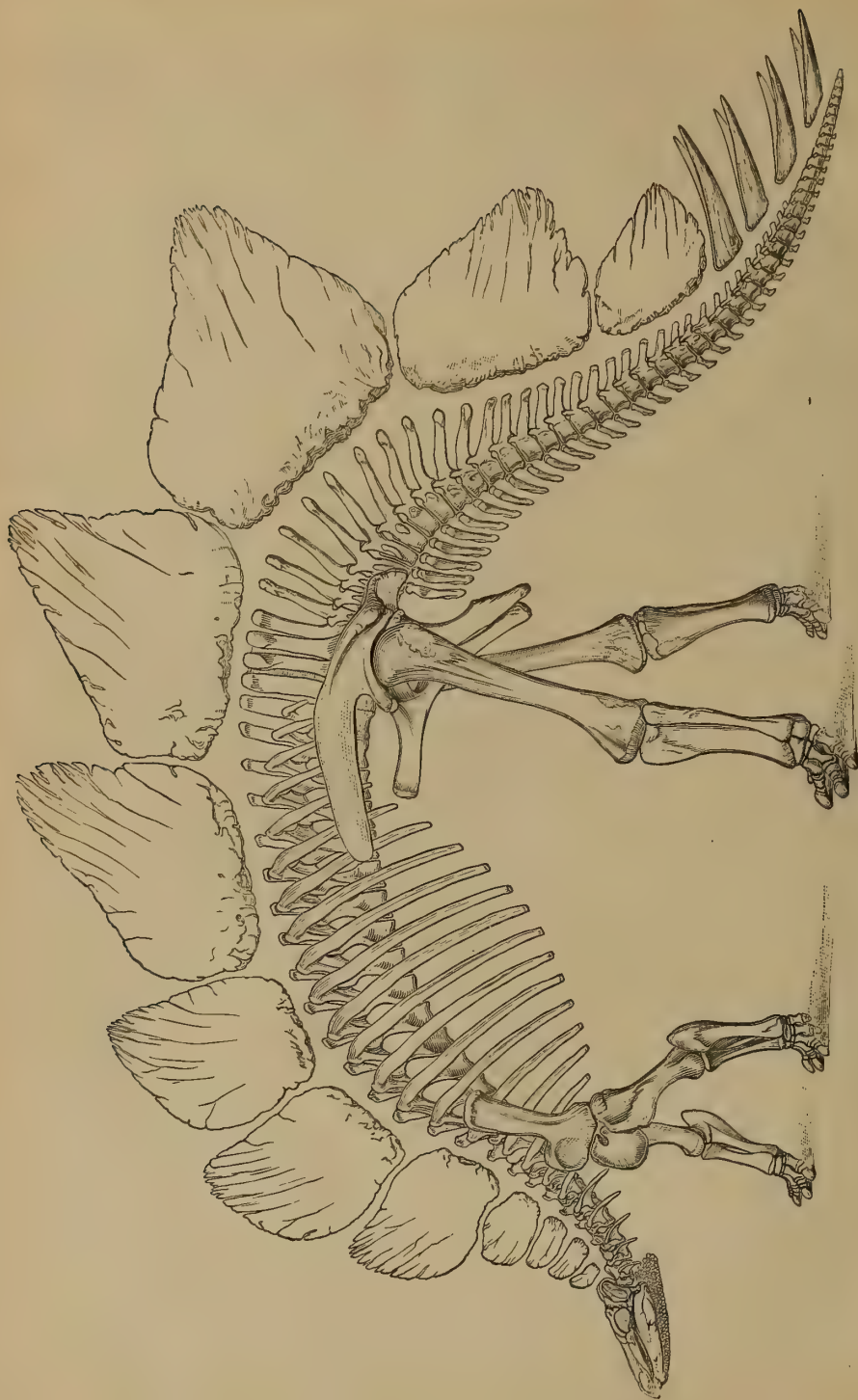


FIG. 1. Restoration of *Stegosaurus unguulatus*. After Marsh. 1/30 natural size.

I. *The Specimen.*

The mounted animal is a combination of two supplementary individuals which together constituted the cotypes of Marsh's original description of *Stegosaurus ungulatus*. They bear the catalogue numbers 1853 and 1858, and contain but little

FIG. 2.



FIG. 2. Mounted skeleton in Peabody Museum, Yale University. Oblique front view.

[Owing to the limitations of the exhibition hall a side view of the skeleton could not be photographed. The correct proportions of the animal, here much foreshortened, can be seen in the frontispiece.]

duplicate bone. These two animals were of nearly equal size, coming from near-by localities of apparently the same geological level in Como Bluff, Wyoming.

In the year 1887,* however, Professor Marsh removed the specimen No. 1858 from the species *S. ungulatus*, making it

FIG. 3.



FIG. 3. Mounted skeleton. Front view.

the holotype of a new species, *S. duplex*. The specific distinctions, as the author gave them, lay entirely in the sacrum,

* This Journal (3), xxxiv, p. 416.

the distinguishing characters being that “In this species [*duplex*] each vertebra supports its own transverse process, or

FIG. 4.



FIG. 4. Mounted skeleton. Rear view.

rib, as in the *Sauropoda*, while in the *S. unguulatus* the sacral ribs have shifted somewhat forward, so that they touch, also, the vertebra in front, thus showing an approach to some of the *Ornithopoda*." The specimen No. 1853 contains no sacral parts except the ischia; the above contrast being made, therefore, not with the other original type of *S. unguulatus*, but with an entirely new sacrum of a much younger individual (No. 1857) arbitrarily referred to that species. In this specimen, the sacral ribs are by no means as robust as in the older animal representing the type of *S. duplex*, and even in the latter a bearing of the rib against the preceding centrum may be observed. In other words, the difference is merely one of degree, which may readily be accounted for on the ground of relative age. The distinction in the form of the ischium of the type 1853 and those of the specimen 1858, which Marsh removed to *S. duplex*, is slight, the difference being mainly in a greater robustness especially in the distal end in the latter, which may readily be an age, sexual or even an individual variation. The two individuals embraced in the mount were much alike, as far as one may judge, differing mainly in proportions, No. 1853 being slightly longer and slenderer of limb. The above evidence was submitted to Professors Osborn and Williston and to Messrs. F. A. Lucas and C. W. Gilmore, the question being as to the advisability of combining the specimens in a single mount. The unanimous conclusion was that the validity of the species *S. duplex* was not proven, as the specific characters mentioned could not be contrasted with those of the remaining type of *S. unguulatus*, and that one was abundantly justified in referring the so called type of *S. duplex* back to its former status as a cotype of *S. unguulatus*, and, further, in combining the two supplemental cotypes in a single erection to represent the species and genus as originally described. Thus the skeleton stands, a few missing bones being modeled in plaster either from their fellows of the opposite side or from another very complete though smaller specimen known in the museum as "*Stegosaurus* Y," catalogue number 1856.

II. The Skeleton.

Some of the most notable anatomical features are the remarkable proportions of the animal with the sharply arched vertebral column, short neck, small head, lank, narrow body and extremely long limbs. The tail, which did not droop abruptly as represented in all previous restorations, was evidently held high above the ground and gives evidence, especially in its posterior half, of extreme sinuous flexibility, and, armed as it was with sharp-edged plates and spines, was the principal weapon of offense and defense against the sanguinary carnivores of that day.

The great power of the fore limbs is at once evident from the size of the scapular arch, the immense rugosities of the humerus and the development of the olecranon process implying a somewhat bent, easily flexed limb excelled only by the huge-headed dinosaur *Triceratops*.

The hind limbs, on the contrary, while powerful, were pillar-like, as the straight shaft and character of the knee joint give positive evidence. The fourth trochanter of the femur, so prominent in bipedal dinosaurs, is lacking, though the origin of the caudo-femoral muscle is nevertheless distinctly indicated. The loss of this trochanter together with the slight development of the pubic peduncle of the ilium precludes the possibility of a bipedal gait, though doubtless *Stegosaurus* is derived from a bipedal ancestry, quadrupedalism being secondarily acquired as in the Ceratopsia, owing to the immense weight of the creature's armament.

The vertebræ are unique in the curious upward prolongation of the neural arch and spine, the transverse processes and zygapophyses being borne high upon the latter, thus producing not only a very rigid back when subject to vertical strains but also raising the ribs and thus increasing the lung and visceral capacity of the body very materially without adding to its breadth. The whole character of the vertebræ and ribs, the latter being T-shaped in cross section near their proximal end, thus giving great stiffness and a broad bearing surface with the minimum of weight, is a wonderful adaptation for bearing the great dermal plates with which the back was adorned.

The feet are large as though to support the creature's weight on yielding soil, the hand evidently possessing five, while the foot bore three, well-developed digits. The semi-digitigrade feet were doubtless enclosed in a fleshy mass as in the modern elephants, while the external indications of the digits were mainly the hoof-like nails.

The body is extremely lank and the hips narrow, the breadth across the deltoid crests of the humeri being the greatest diameter of the animal's frame.

The dentition in common with that of other predentate dinosaurs, except *Hypsilophodon*, is confined to the rear portion of the jaws, the anterior part of the mouth being entirely toothless, very small, and probably ensheathed in a horny cropping beak. The dental battery, while of the same general type as that of *Camptosaurus* or *Iguanodon*, is very imperfectly developed, as the teeth are small, weak structures with crenulated margins and entirely invisible from the outside of the skull and jaws when closed, implying a food of a very yielding character which did not require the forcible mastication of that of *Iguanodon* or more especially of the late Cretaceous

Trachodon, in which the powerful dental battery of 2,000 teeth reaches its highest perfection.

III. Armament.*

The exoskeleton of *Stegosaurus* included five types of structure, of which the first consists of small rounded ossicles found in one instance in position beneath the throat. The known armor of the back consisted of four distinct forms of plates in each of which the dorso-ventral diameter is enormously developed, and often the antero-posterior one as well, instead of a normal horizontal expanse, the result being the production of huge upstanding plates arranged in pairs on either side of the median line of the neck, trunk, and proximal part of the tail, while immense bony spines, possibly varying in numbers with the different species, were borne on the distal end of the latter. The plates are differentiated in that those borne upon the neck are short in fore and aft diameter but with a heavy base divided longitudinally by a depression which was borne astride the transverse processes and cervical ribs. The trunk plates increase rapidly in dimensions to a maximum size of 71×66 cm ($= 28 \times 26$ inches) and a weight of 40 pounds for the pair borne over the pelvis. Here the base was thick and rugose but without the longitudinal cleft. These plates were borne above the transverse processes and the proximal portion of the ribs until the sacrum was approached with its widely expanded neural spines to which the weight was transferred, the two rows of plates approaching each other more nearly than in the more anterior region.

This same type of plate, though with a base somewhat shortened and at the same time much broader, was borne over similar neural spines on the anterior third of the tail. Here the character of the neural spines abruptly changes, the broadened summits being lost and the whole spine very much reduced in height. This point, which marks the beginning of the aggressive, flexible portion of the tail, marks also an abrupt change in the character of the plates, which are now sharp-edged, pointed and bent backward, the base being embedded in the muscles between the neural spines and the vertebral centra. The sharp-edged plates, of which there are three pairs, are followed by four pairs of long spines similarly attached and pointing outward and backward at a decided angle. The longest of these is 25 inches and its present weight $14\frac{1}{2}$ lbs.

The character of the surface of the thin expansion of the plates, which doubtless represents the hypertrophied median

* Lull, this Journal (4), xxix, pp. 201-210, figs. 1-11, 1910.

FIG. 5.

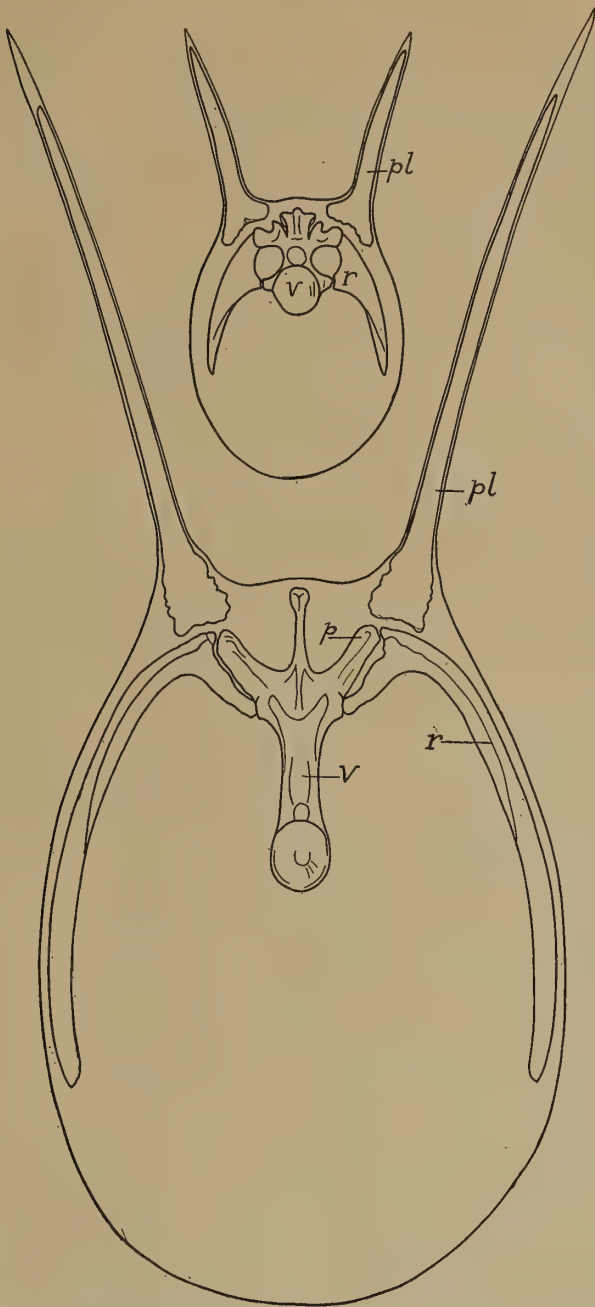


FIG. 6.

FIG. 5. Section of neck. After Lull. *pl*, plate; *r*, rib; *v*, vertebra.
FIG. 6. Section of trunk. After Lull. *p*, transverse process; other letters as in fig. 5.

keel such as one sees in the crocodile and in other armored dinosaurs, and of the spines as well with deep blood-vessel impressions, implies a close-fitting horny integument which must

FIG. 7.

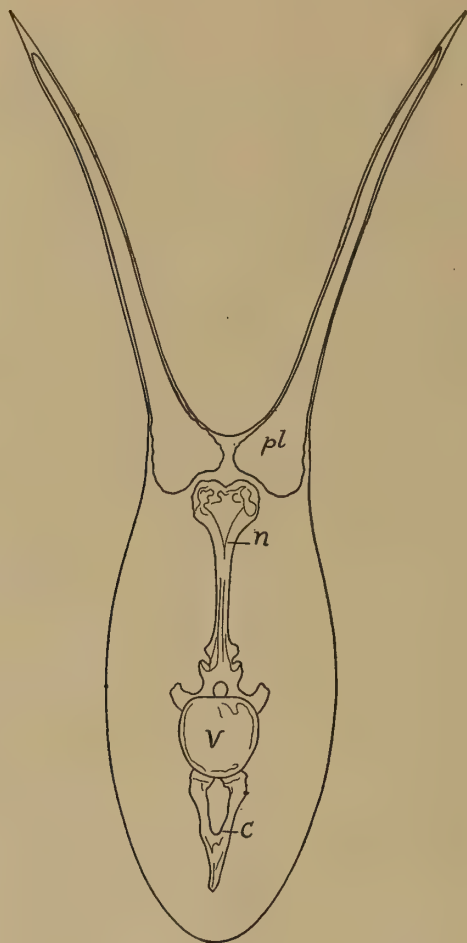


FIG. 7. Section of the proximal part of the tail. After Lull. *c*, chevron; *n*, neural process; other letters as in fig. 5.

have extended some little distance beyond the limits of the bone. The character of the base in both plates and spines, while indicating no articular connection with the underlying endoskeleton, nevertheless gives evidence of a firm cushion of

cartilage of special erecting muscles, and of great thickness of the skin.

There are isolated, highly rugose ossicles, doubtless of dermal origin, associated with the skeleton, which cannot be placed with any degree of assurance, but which may have been scat-

FIG. 8.

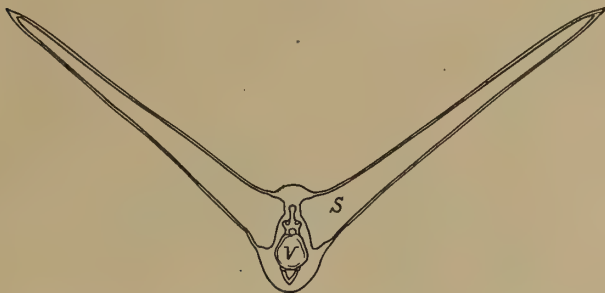


FIG. 8. Section of the distal part of the tail. After Lull. s, caudal spine; other letters as in fig. 5.

tered somewhat at random over the skin or concentrated at especially vulnerable portions of the body.

IV. *The Central Nervous System.*

One of the most remarkable features of this unique reptile lies in the form and proportions of the central nervous system as shown by internal casts and measurements of certain regions of the neural canal.

The brain is remarkable for its extremely small size, the entire cranial cavity, with a length of 1.05^{cm} and a width of 0.30^{cm}, displacing but 56^{cc} of water and having an estimated total weight of but 2½ oz. The total weight of the animal must have exceeded that of the greatest of living elephants, the brain of which averages eight pounds or over fifty times the weight of that of *Stegosaurus*.

In comparing the relative potential intelligence of the two, one has also to bear in mind the great preponderance of the cerebrum over the other parts in the elephantine brain, while in *Stegosaurus* the cerebrum constitutes hardly more than a third of the entire brain weight. The stegosaur brain has a very large olfactory portion, small cerebellum, large medulla, and a hypophysis which is remarkable not only for its size but also for the peculiar shape. The sense of smell was apparently as well developed as may have been that of sight; the auditory sense I am not yet prepared to discuss.

Passing backward along the neural canal, one finds two enlargements; one at the fore limbs, the brachial enlargement,

and the other within the sacrum. In the former, for a space of about four vertebrae, the neural canal, after an average width of 0.25^{cm}, increases to 0.38^{cm} and to a proportionate height in the XIth vertebra.

The neural canal in the sacrum is of startling dimensions, having a maximum enlargement of 1.14^{cm} and a greatest width of 0.95^{cm}, and displaces nearly 1200^{cc} of water, thus giving it a mass more than twenty times that of the brain.

The brachial enlargement was the seat of the innervation of the powerful fore limbs, while that of the sacrum was mainly

FIG. 9.



FIG. 9. Casts of cranial and sacral cavities, showing proportions of brain to sacral enlargement of the spinal cord. 1/3 natural size.

the reflex and coördinating center for the control of the mighty muscles of the hind limbs but more especially of the powerful, active and aggressive tail which constituted the principal means of defense.

V. *Restoration in the Flesh.*

Under the direction of Mr. F. A. Lucas, Curator-in-Chief of the Museum of the Brooklyn Academy of Arts and Sciences and formerly of the U. S. National Museum, two restorations were made by the artist, Charles R. Knight. Of these, the first was a drawing published by Lucas in 1901 in his book,

"Animals of the Past," and again in the Smithsonian Report for 1901, Plate IV. The second restoration is a statuette one-tenth linear dimensions. In the drawing, the plates along the back were placed opposite to each other in pairs and the tail bore four pairs of spines, whereas in the later model the plates alternated and the pairs of spines were reduced to two. The apparent evidence for the alternation of the plates is offered by a specimen in the collection of the U. S. National Museum, in which they are preserved in the rock in the alternating position and in the fact that those of the opposite sides differ materially in shape and size. This Lucas still thinks conclusive, in spite of the fact that no known reptile has alternating dermal scutes, and that the probabilities are that the one row of the plates, as preserved in the matrix, has shifted forward or backward during maceration or in the subsequent movement of the rocks, as an oblique crushing of fossil bones is a very familiar phenomenon. The disparity in size and shape of the two plates of a pair is not surprising when one considers that the entire hypertrophy of the plate is in a sense abnormal and is comparable to the growth of the antlers of deer, notably the caribou, of which those borne by a single individual are rarely if ever precisely similar in size, weight, form, or even in the number of points.

The reduction of the number of caudal spines was also due to the evidence offered by two other specimens, also in the U. S. National Museum, with the spines *insitu*. The type of *Stegosaurus ungulatus*, however, shows four pairs and no further evidence of the duplication of bone, so that it is evident that they all belonged to one individual. It would seem, therefore, as though the number both of spines and plates may well have been a specific character if not an individual or possibly sexual variation.

During the erection of the Yale specimen, an admirable opportunity was offered for another model of which I have taken advantage, this time using a scale of one-fifth to reduce still further the margin of error. (Fig. 10. See Plate II.) The model is based not alone upon the proportions and positions of the various bones as in the mounted skeleton, but also upon studies of the individual bones made with a view of plotting thereon the attachments of the various skeletal muscles of the body and limbs. In this work, a small alligator was dissected and for comparison a specimen of *Sphenodon* (*Hatteria*) as well. I was also aided by the admirable work of v. Huene on the musculature of *Plateosaurus erlenbergiensis* (Die Dinosaurier der Europäischen Triasformation, Jena, 1908) as well as by Haughton's work on the muscular anatomy of the crocodile. One side of the model, the left (fig. 10), shows the superficial

FIG. 10.



FIG. 10. Model of *Stegosaurus unguulatus*, based upon the mounted skeleton. Left side bereft of the integument, showing the superficial musculature. Modeled by R. S. Lull.

musculature of the body, the outlines of both ilium and scapula being indicated as landmarks and also the skull and the dermal plates, the latter bereft of their outer sheath of horn. The immense power of limb, neck and especially of the tail is shown, together with the slips of dermal muscle which stiffened the armor in time of stress, such as are seen beneath the scutes of the alligator. The right side of the model is clothed in the skin, which is indicated as of a leathery, elephant-like texture, with the shield of throat ossicles, as well as the scattered ones over the entire frame.

The gape of the mouth is represented, as in my previous models of the *Ceratopsia*, as extending but a short distance back, to the point where the dental series begins, owing to the necessity of muscular cheeks on the part of a masticating herbivorous form, in order to retain the food in the mouth. The gape thus includes only the prehensile part of the mouth, which is very small as compared with the vast body bulk which the creature is forced to sustain.

VI. *Principal Measurements.*

Length between perpendiculars	19 ft.	5 in.
“ of tail between perpendiculars	8 “	8 “
Height of sacrum	9 “	11 “
“ highest plate	11 “	10½ “
“ muzzle	3 “	4 “
“ tail tip	4 “	1½ “
Width of hips	3 “	5½ “
“ shoulders	3 “	10½ “
“ chest	3 “	8½ “
Height of shoulder	4 “	4 “
“ elbow	2 “	7½ “
“ hip	7 “	6 “
“ knee	3 “	3½ “

Present weight of the fossil skeleton, 1917 lbs.

Estimated live weight, between 7 and 10 tons.

VII. *Life Conditions and Relationships.*

The genus *Stegosaurus* is confined exclusively to the Morrison formation, upper Jurassic or lower Cretaceous of Wyoming, U. S. A., strata of nearly equivalent age to those of the European Wealden. The character of the environment was probably similar to the conception offered by Hatcher, who believed that the Morrison beds were deposited “over a comparatively low and level plain which was occupied by an interlacing system of river channels. The climate was warm, and the region was overspread by luxuriant forests and broad

savannas * * * conditions doubtless similar to those now found about the mouth of the Amazon and over some of the more elevated plains of western Brazil." In spite of the numerous remains of plant-feeding animals, the actual relics of fossil plants are relatively few, nor does the sediment in which these remains are found give other evidence of abundant vegetation. Hatcher's inference of "luxuriant forests" is, therefore, as yet unproved by direct evidence.

The water areas, as has been shown,* were doubtless the dwelling places of the huge contemporaneous Sauropods, while *Stegosaurus* was terrestrial and possibly frequented the forests in search of the tender but luxuriant vegetation upon which it browsed. It may well be that the extreme relative narrowness was an adaptation to forest conditions and afforded ease of passage between the trunks of the tree ferns, conifers, and other vegetation of that day. *Stegosaurus* is rarely found entombed with sauropod dinosaurs, but, on the contrary, is often found isolated or in company with the bipedal unarmored herbivorous *Camptosaurus*, the nearest equivalent of the European *Iguanodon*, and with the fleet *Dryosaurus*; and of carnivores, the agile *Caelurus* and the blood-thirsty *Allosaurus*, which was probably its greatest enemy.

I imagine much of the bizarre character of the armor of *Stegosaurus* was due to the over-specialization accompanying racial old age, but it was nevertheless in many respects admirably adapted to meet on a more or less equal footing the huge well-armed carnivore last mentioned. It would seem as though *Stegosaurus*, instead of presenting his front to the enemy, turned the rear, possibly crouching low in front as the crocodile does, and, with vigorous sweeps of the terrific tail, impaled the exposed ventral portion of the bipedal carnivore upon the caudal spines and sharp-edged plates.

The long hind limbs imply a rather rapid progression, while the powerful fore limbs were not only for locomotor purposes but for rapidly pivoting the body to prevent either a frontal or flank attack.

Of the evolutionary history of *Stegosaurus*, we know but little. It seems, however, to have been a migrant from Europe, having its nearest relative in *Omosaurus* (*Dacentrurus*), remains of which are known as far back as the Dogger (Bathonian) of England.

In *Omosaurus durobrivensis* from the Oxfordian of England, which I studied this summer in Cambridge and in the British Museum of Natural History, I find what may readily be a direct ancestor of the American types. The plates and spines

* Lull, Dinosaurian Distribution, this Journal, xxix, p. 10, 1910.

are present, and, in every respect, the older animal differs only in being of a more generalized character. On the other hand, *O. armatus* of Owen, from the Kimmeridgian, though nearer *Stegosaurus* in time, is less like it than is its predecessor in the rocks. *O. armatus* would seem, therefore, to belong to a different phylum, in many respects more conservative than the true stegosaurs.

That *Stegosaurus* belonged to the predentate dinosaurs and to the armored Stegosauria, is certain. It is not, however, in the direct line of descent, but rather an over-specialized side branch, which was apparently totally blotted out after Morrison time, despite the fact that most of its associates, except the Sauropoda, lived on.

The spinescent character of *Stegosaurus* is of course indicative of racial senility, but the modernizing of the flora and the restriction, doubtless, of the special food plant to which the feeble mouth armament was adapted, may have been the immediate cause of extinction.

The skeleton has been mounted under my direction by Head Preparator Hugh Gibb, assisted by W. S. Benton, and is a monument to their skill and industry.

ART. XL.—*The Use of Metallic Potassium in Determining Halogens in Benzol Derivatives*; by C. H. MARYOTT.

[Contributions from the Kent Chemical Laboratory of Yale Univ.—ccxvi.]

A METHOD for the estimation of halogens in organic compounds by reduction with sodium and alcohol was described a few years ago by Stephanoff.* The writer recently attempted to use this method in determining chlorbenzol, but the results obtained were very irregular and unsatisfactory. Before enough sodium had been added to effect complete reduction, the liquid became pasty owing to the separation of sodium ethylate, and this localized and greatly hindered the action of the sodium. By increasing the amount of alcohol above that recommended by Stephanoff, the sodium ethylate could be kept in solution, but the large volume of liquid retarded the reduction, and thus increased both the time and the amount of sodium required. In all cases the results of the analyses were low.

A failure to obtain satisfactory results with Stephanoff's method has likewise been reported by Bacon,† who, however, devised a modification of the method, in which accurate results were obtained by heating the mixture for an hour after the solution of the sodium, thus utilizing the action of the sodium ethylate upon the halogens. Bacon's method was not tried by the writer, as the article cited came to his attention after the completion of the experiments described below. The long time required, about two hours, would seem to be a disadvantage, and the fact that certain of the benzol halogen derivatives such as monochlor- and monobrombenzol are attacked but little, if at all,‡ by boiling with sodium ethylate, a possible source of error in the method.

The use of potassium instead of sodium as a means of obtaining a more rapid reduction was suggested to the writer by Professor R. G. Van Name, and upon trial proved to be a great improvement. As the action of potassium upon alcohol is very energetic, a mixture of one volume of 98 per cent alcohol with two of thiophene-free benzol was employed. The presence of thiophene had to be avoided to prevent the formation of potassium sulphide, which would interfere in the subsequent estimation of the halogen. The reduction was

* Ber., xxxix, 4056, 1906.

† Jour. Am. Chem. Soc., xxxi, 49, 1909.

‡ The writer boiled monochlor- and monobrombenzol in a concentrated solution of sodium ethylate for three hours, but failed to get any test for halogens upon acidifying and adding silver nitrate. Bacon states in his article that he was unable to convert monobrombenzol into phenetol by heating with sodium ethylate, although 25 per cent of the chlorine was removed from hexachlorbenzol by the same treatment.

carried out in an Erlenmeyer flask, and very little heating was required so that a plain glass tube about 50^{cm} in length, without water cooling, served as a condenser.

The test analyses given below were carried out as follows: The substance was weighed out in the Erlenmeyer flask, 10–15^{cc} of the alcohol-benzol mixture added, and the potassium, in small pieces, gradually dropped in through the tube. The weight of potassium required was about ten times* that called for by the equation



A small amount of potassium ethylate usually separated out during the action of the metal, but seemed to have no bad effect upon the reduction. After the action had become less vigorous, about 2^{cc} of alcohol were added, the flask carefully heated and gently shaken from time to time until the potassium was all dissolved. The contents were then shaken with water, the water layer acidified with nitric acid, and the halogen precipitated and weighed as the silver salt. The use of Volhard's volumetric method in estimating the halogens, as done by Stephanoff and Bacon, would, of course, have been feasible, though somewhat less accurate. The time required for an analysis, exclusive of weighings, was about twenty-five minutes.

A series of analyses gave the following results:

CHLORBENZOL, 31.52 per cent Chlorine.

	Weight taken gram.	Per cent of chlorine found	Per cent error
(1)	.4036	31.62	+ .1
(2)	.3533	31.46	— .06
(3)	.4181	31.51	— .01
(4)	.3278	31.44	— .08
(5)	.4087	31.48	— .04
(6)	.4245	31.53	+ .01
(7)	.3324	31.52	± .0

(8)	.3530	30.39	— 1.13

With the exception of No. (8) the agreement is satisfactory. The low result here is doubtless due to the use of an insufficient amount of potassium, as only six times that required by theory was added. The chlorbenzol was twice redistilled and that portion distilling between 131.5° and 131.7° used in the analyses.

*Stephanoff's method calls for twenty-five times the theoretical amount of sodium.

BROMBENZOL, 50.92 per cent Bromine.

	Weight taken gram.	Per cent of bromine found	Per cent error
(1)	.3976	51.29	+ .37
(2)	.3921	51.31	+ .39
(3)	.3928	51.31	+ .39

The results are very concordant but slightly high, probably due to impurity in the brombenzol, as the sample used was a commercial product once redistilled.

HEXACHLORBENZOL, 74.71 per cent Chlorine.

	Weight taken gram.	Per cent of chlorine found	Per cent error
(1)	.1301	75.39	+ .68
(2)	.1190	75.15	+ .44

The material used was Kahlbaum's product once recrystallized from hot benzol.

p-CHLORANILINE, 27.81 per cent Chlorine.

	Weight taken gram.	Per cent of chlorine found	Per cent error
(1)	.3081	27.93	+ .12
(2)	.3456	28.00	+ .19

To test the relative efficiency of sodium and potassium in their capacity as reducing agents, an analysis of chlorbenzol was carried out exactly as above described except that sodium (ten times the theoretical amount) was used in place of potassium. Only 84 per cent of the total chlorine was found.

It is therefore evident that potassium is very much more effective as a reducer than sodium, and is consequently better adapted for use upon such substances as the halogen substituted benzols, which belong to the most difficultly reducible class of organic halogen compounds. In the experience of the writer it gives, under the conditions outlined above, a complete reduction with the minimum expenditure of time and trouble.

ART. XLI.—A New Genus of Peccaries; by F. B. LOOMIS.

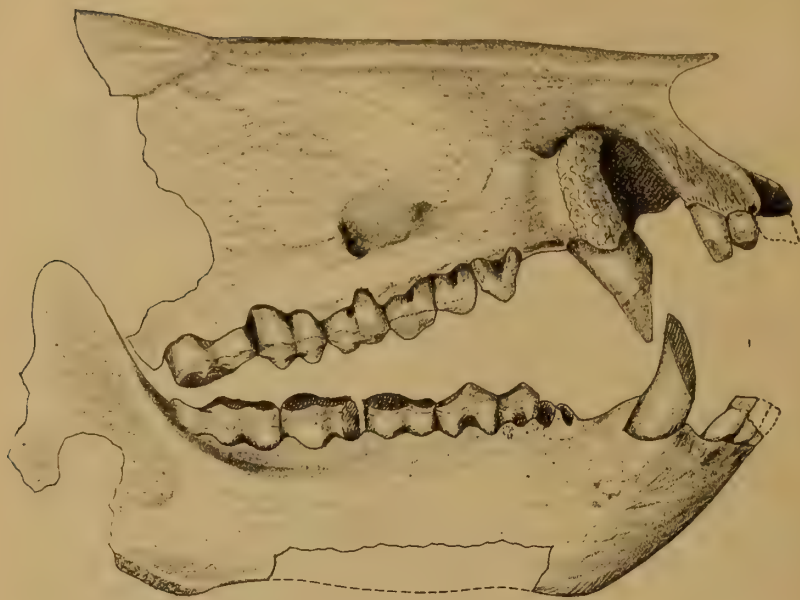
SINCE their introduction into North America in the Oligocene the peccaries have never been an abundant group, but have nevertheless held their own and progressed steadily though slowly toward their present structure. During the summer of 1908 the Amherst party found in the "breaks" about two miles southeast of the Raw Hide Buttes in Converse Co., Wyo., and in the sandstones of the Upper Harrison beds, the skull (lacking the brain case) and lower jaws of a peccary which is intermediate in development between *Desmathyus* of the Rosebud formation and the modern peccary, *Tayassu*. The specimen is No. 2047 in the Amherst College Museum and includes the muzzle in lower jaws, the dentition being complete except that upper incisor 1 and premolar 1 are wanting. The individual is old and the teeth well worn. The new form differs from the earlier genera and *Desmathyus* in having but 3/3 premolars, and is distinct from the modern type in that the third incisor is still retained; though the incisor series has already begun to assume modern character, in that the first incisor is greatly enlarged. With this form it will be seen in the table on page 384 that the series of peccaries is very nearly a perfect one.

Pediohyus ferus gen. et sp. nov.

The muzzle is moderately high with a straight or slightly convex upper boundary inclosing an ample olfactory chamber very like that of the modern peccary. The opening of the infraorbital foramen is well back, lying just over the front of the first molar. The alveolus for the upper canine is greatly swollen on the outside into a rough projecting tubercle. In front of this there is a correspondingly deep pit for the reception of the lower canine.

The first upper incisor is wanting but the greatly enlarged alveolus shows that it was of the modern type, broad and elongated and two to three times the size of the other incisors. Incisor 2 is less than half the size of the first, and has a simple blunt wedge-shaped crown. The third incisor is still smaller but by no means vestigial. Between it and the canine is a gap of some 20^{mm}, which represents the width of the pit for the lower canine. The upper canine is a powerful tooth but slightly bent backward, and approximately oval in cross section. The anterior face is beveled off with wear. It is hard to say what caused the wear as the tooth does not meet the lower canine, but use must have ground the major part of the tooth away.

FIG. 1.

*Pediohyus ferus.* Type specimen $\frac{1}{2}$ nat. size.

There is no upper premolar 1, the interval behind the canine occupying 15^{mm} . The second premolar is small with a single primary cusp near the front and a smaller one behind. The third premolar is wider and has two anterior cusps which are higher and stouter than the small ones on the back of the crown. The fourth premolar is distinctly molariform, though distinctly smaller than any molar and having but three distinct cusps, the two anterior and the outer posterior one, the inner posterior cusp being replaced by a low ridge (very like a strong cingulum). All these premolars are much less progressive than the corresponding teeth in the modern *Tayassu*.

The molars have low quadratical crowns and have been so much worn that the details are not now clear. Each seems to have had four primary cusps, and the cingulum as well or better developed than in the recent genus.

The incisors of the lower jaw are simple and normal except that the third one is less reduced than in the recent peccary. The canine is a powerful tooth, which in the type specimen is much worn and beveled on the anterior face. The first premolar is wanting, the second being separated from the canine by a diastema of 23^{mm} . Judging from the alveolus, the tooth

was small and simple. The two succeeding premolars are much larger, but in this specimen are too worn to admit careful description. The molars are low crowned, the third being provided with a large heel.

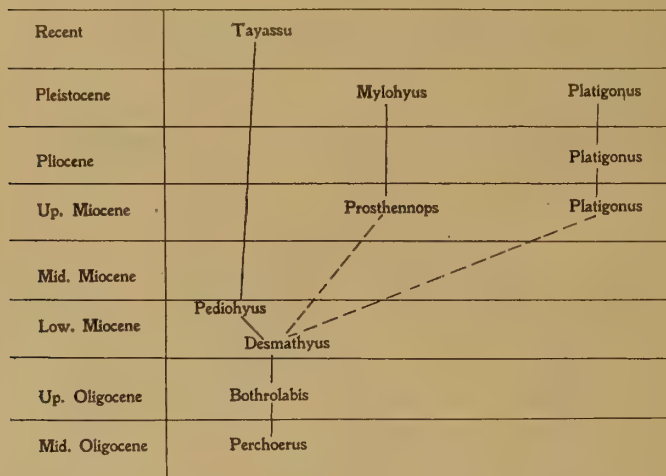
Measurements.

Length of upper dentition	170 ^{mm}
Width of incisor 2	8
Width of incisor 3	5½
Length of upper premolar series	35
Length of premolar 2	11
Length of premolar 3	11
Length of premolar 4	13
Length of molar series	58
Length of molar 1	19
Length of molar 2	19
Length of molar 3	20
Length of lower premolar series	41
Length of lower molar series	64

The following table shows the relative development of the dentition of the various genera of this Tayassuinae family or series:

	Age	Dentition	Incisors	Premolars	
Perchoerus	Mid. Oligocene White River	$\frac{3}{3} \frac{1}{1} \frac{4}{4} \frac{3}{3}$	Equal	All simple	No notch for lower canine. Skull rather brachicephalic.
Bothrolabis	Up. Oligocene John Day	$\frac{3}{3} \frac{1}{1} \frac{4}{3} \frac{3}{3}$	Equal	All simple	Notch for lower canine. Skull mesocephalic.
Desmathyus	Low. Miocene Low. Rosebud	$\frac{3}{3} \frac{1}{1} \frac{4}{3} \frac{3}{3}$	In. 1 enlarged In. 3 reduced		Notch for lower canine. Skull mesocephalic.
Pediohyus	Low. Miocene Up. Harrison	$\frac{3}{3} \frac{1}{1} \frac{3}{3} \frac{3}{3}$	In. 1 enlarged In. 3 reduced	P. 4 slightly molariform	Notch for lower canine. Skull mesocephalic.
Tayassu	Up. Miocene — Recent	$\frac{2}{3} \frac{1}{3} \frac{3}{3} \frac{3}{3}$	In. 1 enlarged In. 3 lost	P. 4 molariform P. 3 less " P. 2 " "	Shallow notch for lower canine. Skull mesocephalic.
Platigonus	Up. Miocene — Pleistocene	$\frac{2}{3} \frac{1}{1} \frac{3}{3} \frac{3}{3}$	In. 1 enlarged	Simple	2 or less transverse crests on upper premolars and molars. Skull mesocephalic.
Prosthennops	Up. Miocene	$\frac{2}{3} \frac{1}{1} \frac{3}{3} \frac{3}{3}$	Reduced	P. 3 and 4 molariform	Skull dolicocephalic.
Mylohyus	Pleistocene	$\frac{0-2}{3} \frac{1}{1} \frac{3}{3} \frac{3}{3}$	Vestigial or wanting	P. 2-4 molariform	Skull dolicocephalic.

From the above it will be seen that the various genera of peccaries represent three lines of development, a mesocephalic type beginning with *Perchoerus* and ending in *Tayassu*, a dolicocephalic type including *Prosthennops* and *Mylohyus*, and the aberrant genus of *Platigonus*. The series is distinctly an American one, appearing first and doubtless by migration from Asia during the lower Oligocene. A couple of species have been doubtfully referred to *Hyotherium*, and it was probably some primitive member of that genus which on reaching this side soon developed the peculiarities which separate the peccaries from the pigs. Life in a more open country might well have started the modifications which are especially along the line of slenderer build and speed. The following diagram may graphically indicate the general relationships of the known genera:



Beside these there are a few forms known only by fragmentary material, like *Chænohyus*, *Leptochœrus*, and *Nanohyus*, which cannot be placed in their relationships until more complete material is found.

Amherst College.

ART. XLII.—*The Geology and Topography of the Serra de Jacobina, State of Bahia, Brazil*; by JOHN C. BRANNER.

THE Serra de Jacobina, taken as a whole, is the most beautiful and most majestic mountain range in Bahia, and one of the finest in all Brazil. The range is known at different places by more than a dozen different names, these names, in accordance with the popular custom in the interior, being taken from the various cities, towns, villages, and estates situated along its base.

For the sake of geographic and geologic clearness it seems best to call the range as a whole the Serra de Jacobina, for that is the name by which it is most widely and most appropriately known in Brazil, though it is called the Serra de Saude in Barão Homem de Mello's Atlas do Brazil. The local names may well be left for the various high peaks in the range.

The profile given by Dr. Allen in Hartt's Geology and Physical Geography of Brazil, at page 310, gives an erroneous impression of the topography about the city of Jacobina. This impression has been further deepened by the other erroneous idea that there is one great mountain-range—the so-called Serra do Espinhaço of Eschwege—extending across this region.* As a matter of fact there are two very distinct ranges at and near Jacobina, to say nothing of others farther west, while, so far as the Serra do Espinhaço is concerned, a field examination of the topography and geology of the region lends little or no support to the theory of the existence of such a range in this part of the state of Bahia.

The southern extremity of the Serra de Jacobina is nearly three hundred kilometers on an air-line northwest of the city of Bahia. Its southern end is on the north side of Rio Jacuipe, just southeast of the village of Canna Brava, and some thirty-five kilometers south of the city of Jacobina. From this point it runs nearly due north past Jacobina, Saude, Campo Formoso, Villa Nova, and Jaguararý, and ends just west of the station of Jurema, on the Bahia and São Francisco railway—a total distance of 225 kilometers on a line. Though it widens considerably at some places, its average width is only about six or seven kilometers. The altitudes of the highest points in the range have not been measured. The writer has determined the altitudes of a few prominent peaks, but none of the peaks climbed by him was the highest. The highest peak ascended

* O. A. Derby. The Serra do Espinhaço, Brazil, Jour. Geol., xiv, 347-401. This article reproduces Dr. Allen's profile and sketch of the Serra do Tomador.

is one called the Serra de Sant'Anna, ten kilometers north of the city of Bomfim. This peak has an altitude of 1100 meters above tide level (three aneroid measurements). There are considerably higher points in the range farther south in the vicinity of Saude, Jacobina, and Canna Brava.

Sections across the Serra de Jacobina made at different places differ but little from each other. Everywhere the rocks are conglomerates, quartzites, and talcose shales or schists with steep dips toward the east. Along the western base of the range these sedimentary beds rest upon granites or old eruptives, while on the east side also the granites and other crystalline rocks come close up to its base. The city of Jacobina stands at the western base of the Serra de Jacobina where that range is cut in two by the Rio Itapicurú. Near that city on the west side of the range the granites and old crystalline rocks extend westward from the foothills of the Serra de Jacobina to and up the slope of the Tombador range. It should be clearly understood that the Serra de Jacobina is entirely dis-

FIG. 1.



FIG. 1. Section along Rio Itapicurú at Jacobina where it cuts through the Serra de Jacobina.

tinct from the Serra do Tombador, which is a parallel range some thirty kilometers west of Jacobina. The Jacobina range is formed of sedimentary beds, mostly quartzites, alternating with slates or schists, standing nearly on end, and is high, narrow, rugged and picturesque. The Tombador range is low, of even horizontal crest, made of nearly horizontal sandstones and quartzites that rest upon granites and form a vertical escarpment along the east face of the mountain, while on the west they dip gently westward and pass beneath the Salitre valley. The diagram given at page 337 of the article on the Serra do Tombador† shows the relations of these two mountain ranges to each other both topographically and geologically.

The sections examined across the Serra de Jacobina are here given in more detail.

The city of Jacobina is at the parting between the granite area west of the Serra de Jacobina and the quartzites that form the serra itself. The actual contact between the two kinds of rocks is not exposed on Rio Itapicurú in the town. It is quite evident, however, that this contact crosses the middle

† This Journal, vol. xxx, p. 335.

of the city just west of the Conceição church, and close to the city jail. North of the city this parting comes out clearly in the vegetation. The bare quartzites are covered with a stunted growth of bushes, while the vegetation on the granites is more vigorous and abundant, and its color is of a brighter green. Along this west flank of the range toward the north one sees clearly the eastward dip of the sedimentary series forming the serra and the strike which is always parallel with the range itself. Immediately south of the Itapicurú near Jacobina the sandstones and quartzites near the contact are so jointed that one can hardly find a block a foot in diameter.

The influence of the rocks on the vegetation is noticeable south of the river. The "monte" or peak with the cross at its summit is just south of the city and 150 meters above it. The north end of this ridge is of green-stained, flinty quartzite conglomerate. The pebbles of these conglomerates are often as large as hen's eggs, and the metamorphism is so complete that the outlines of the pebbles are often obscure. A kilometer or so farther south along this same ridge pebbles 15 centimeters long are common. The fracturing or jointing of some of these conglomerates and quartzites is remarkable. Over some exposures there are three sets of parallel joint-planes intersecting each other with striking regularity at angles of thirty degrees, and breaking the beds into small angular blocks. Another striking characteristic of these basal conglomerates is that the well-worn pebbles of which they are composed are themselves made of quartzitic sandstones. In other words, these conglomerates are not derived from the underlying granitic rocks, but from an older series of sediments. Some sixty-five kilometers farther north the Rio Itapicurú cuts through the range, but this section was not examined by the writer.

Something more than a hundred kilometers north of Jacobina a good section of the Jacobina range is exposed near the town of Campo Formoso, where it is again cut by a stream, the Rio do Campo Formoso or da Agua Branca. At this place the mountain range as a whole is made up of four parallel quartzite ridges dipping eastward at a high angle. The hard beds of the series are quartzites very much like the so-called itacolumites of Minas Geraes, while the yielding beds are talcose schists. The town of Campo Formoso at the mountain's western base stands on granites, and the waters that unite at this place to form Rio do Campo Formoso flow almost exclusively from the granite area that forms the rolling country immediately west of the Serra-de Jacobina. The plains that extend eastward and southeastward from the serra's eastern base are also of granites, mica schists, and other crystalline rocks, with here and there a quartzite ridge rising above the

general level. The mica schists are exposed on the road about two and a half kilometers due south of Monte Tabor. The quartzites and other rocks of the Monte Tabor range, which is the easternmost member of the Jacobina range, all dip toward the southeast at a high angle.

About twenty kilometers northeast of Rio Agua Branca another section across the Serra de Jacobina was examined on

FIG. 2.



FIG. 2. Section across the Serra de Jacobina along Rio Campo Formoso or Agua Branca.

and in the vicinity of the road between Villa Nova and Campo Formoso. The general structure on this road is shown in the accompanying section (fig. 3).

In this section the summit of the Morro da Mina has an elevation of 950 meters a. t. or 403 meters above the railway

FIG. 3.



FIG. 3. Section across the Serra de Jacobina west of Villa Nova.

station at Villa Nova. A dip measured on Morro da Mina is 60° S. 40° E. magnetic. The rocks are the usual quartzites more or less decomposed at many places, and red and purple shales interbedded with them.

The next section across this range to which attention is called is west from the railway station of Jaguararý and twenty-five kilometers north of Villa Nova. The distance through the range at Jaguararý is about six kilometers on a straight line, and about nine by the trail. The drainage does not cut entirely through the range here as it does at Campo Formoso and Jacobina. The rocks exposed at and about Jaguararý are all granites. These granites are cut by the railway at several places south of the town, and they are well exposed in bosses from thirty to fifty meters across.

The serra at this place is made up of four quartzite ridges, the three parallel valleys being cut in talcose schists similar to

those found in the other sections. The schists are also exposed on the plain between the easternmost quartzite ridge and the town of Jaguararý. Throughout the whole section the rocks dip eastward; one dip measured in the purplish quartzites of the eastern range was due east at an angle of sixty degrees.

West of the range the rocks of the plain are granites and gneisses and these rise more than half way up the western

FIG. 4.

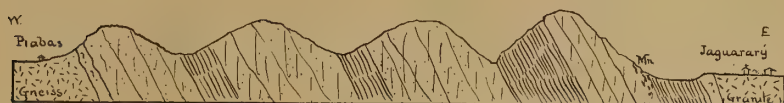


FIG. 4. Section across the Serra de Jacobina between Jaguararý and Piabas. Length of the section, ten kilometers.

slope of the mountain. The actual contact between the sedimentary series and the crystalline series was not seen; those observed nearest the quartzites are soft cream-colored rocks that have the appearance of being composed of decomposed feldspars. Below these are laminated gneisses in an advanced stage of disintegration.

At my request Mr. Roderic Crandall made a trip across the serra along the upper portion of the Rio do Poço Comprido, which cuts across the Jacobina range twenty kilometers north of Jaguararý. Mr. Crandall found the range at that place to be made up of four parallel ridges of quartzite whose beds dip north eighty degrees east at an angle of seventy degrees. Granites form the plains both on the east and the west sides of the serra. The structure is, therefore, the same as that shown in the other section across the range.

The examples given are enough to show the remarkably uniform structure throughout of the Jacobina range. They also show at all the points examined the granites, gneisses or other old crystalline rocks on both sides of the range. The relations of the granites on the west side of the range to the sedimentary series seems to be fairly clear: the form, continuity, and position of the parting suggest, if they do not positively prove, that the sedimentary series was laid down upon the granites. On the east side of the range, however, the contact between the granites and the sediments has not certainly been observed, and there is, therefore, more or less doubt about the relations of the sediments of the serra to the crystalline rocks of the plains to the east. Everywhere the four main ridges of the serra are of extremely hard quartzites, while the valleys are cut in soft talcose schists.

The following theories have been entertained in an attempted explanation of the facts thus far gathered in regard to the Serra de Jacobina:

I. The theory of a single synclinal fold having the two eastern members turned back so far that the beds have the same dip as the western ones. The relations would then be such as are suggested by the accompanying section.

FIG. 5.

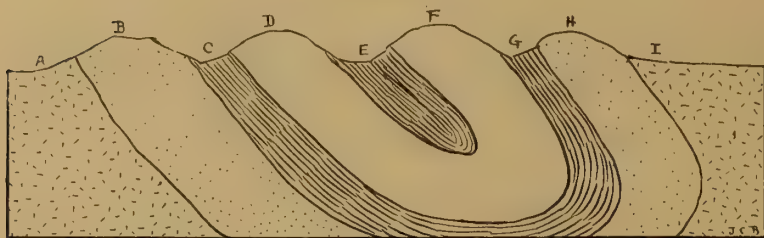


FIG. 5. Theoretical section to show the surface repetition of beds in a synclinal fold.

If this were the correct explanation of the structure of the range one should expect to find the ridges *B* and *H* to show such similarity in material and sequence of their beds as are commonly found in sedimentary deposits at similar distances from each other. The same would be true of ridges *D* and *F* and of the valleys *C* and *G*. At *E* one would expect to find a double thickness of a single bed or group of beds. To put it differently: starting at *E*, the axis of the syncline, one should find the same or nearly the same sequence of rocks in passing from *E* to *A* as he would in passing from *E* to *I*.

It cannot be said that the study of any of the sections examined across the range has been sufficiently critical to settle this point beyond question. The facts that appear to bear upon it, however, are mostly unfavorable to the theory of a synclinal fold. These facts are here given very briefly.

1. Along the eastern face of the range is a series of mangiferous schists or shales that is repeated on its western side at only one place, so far as seen, and that is at and north of the village of Brejão. The distance through the range on this theory, however, is large enough to diminish considerably the importance of this particular fact.

2. So far as is now known, the conglomerates of the western ridge of the range are not repeated in the eastern ridge. Here again the distance through the range may be urged against the probability of the similarity of the beds over so wide a zone.

II. The second theory is that of the repetition of the same beds by four parallel faults. This theory would require but one series of quartzite beds and an overlying series of schists or slates. Four parallel faults, as suggested in the accompanying figure, might yield the general structure of the range.

FIG. 6.

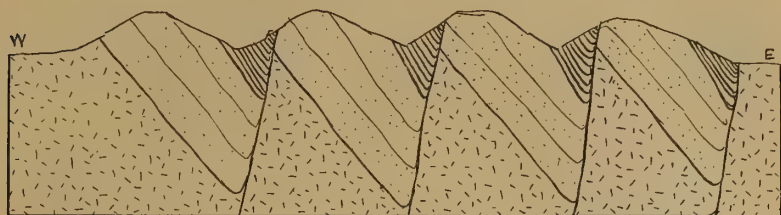


FIG. 6. Ideal section across the Serra de Jacobina on the theory of its having been formed by four parallel faults.

The chief objection to this theory is the great length of the range and its apparently uniform character throughout. It would be very remarkable to find four faults so evenly spaced for 225 kilometers and following each other in the curves made by the range throughout that entire distance.

A second objection is that the manganiferous shales or slates near Villa Nova and Jaguararý are not repeated in the valleys within the range as we should expect if the structure were produced by such a series of faults. Similarly the heavy con-

FIG. 7.

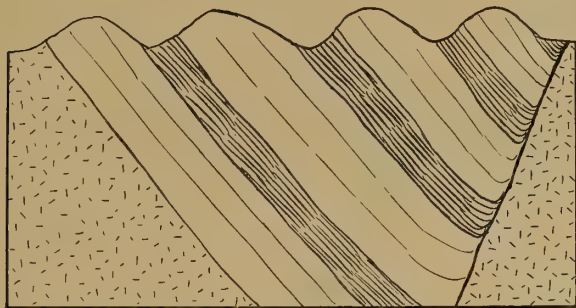


FIG. 7. Section across the Jacobina range on the theory of a single fault with the downthrow on the west.

glomerates at the base of the series at Jacobina are not repeated in the easternmost ridge of the range.

III. The third theory is that of a single fault along the eastern face of the range, with the downthrow on the west and the subsequent denudation of the uplifted eastern side. According to this theory, the structure would be something like that shown in the accompanying figure.

There seems to be no special objections to this theory unless it be the great depth required for the theoretical single fault.

The remarkable fact that the great Serra de Jacobina is cut entirely in two at several places by streams flowing through steep-sided gorges will be discussed in a later chapter on the geography of the State of Bahia.

The following questions should be kept in mind by those who may hereafter have opportunities to study the geology of the Jacobina range:

I. Are there always four parallel ranges, or is this appearance misleading?

II. Is the Jacobina range of the same geologic age, and has it the same general history as the smaller quartzite ridges on the plains both east and west of the range, and mentioned in this Journal, Oct., 1910, p. 263.

ART. XLIII.—*On an Indirect Method for Determining Columbium and Tantalum*; by H. W. FOOTE and R. W. LANGLEY.

Introduction.

THE determination of tantalum and columbium in mixtures of their oxides has always been one of the difficult operations in analytical chemistry. The method for separating the two metals was devised by Marignac* and consisted in separating by crystallization the difficultly soluble potassium-tantalum fluoride from the more soluble columbium salt. This method, with various minor modifications, is still the one commonly used. The operations involved are tedious and the results are only approximate. Judging by our own experience, the method requires some practice before even approximate results can be obtained. The reason why the results are inaccurate is first, because the tantalum salt obtained is not quantitatively insoluble, so that tantalum is left in the filtrate with the columbium, and second, because of the tendency of columbium to crystallize to a limited extent with the tantalum double fluoride.

Two volumetric methods have been proposed, both depending on a preliminary reduction of columbium to a lower oxide and titration with potassium permanganate. By the first of these methods† columbium is reduced by zinc in strong hydrochloric acid solution, and titrated with potassium permanganate which has been standardized by means of a pure columbium salt. In the second method‡, columbium in a solution containing succinic acid is reduced by amalgamated zinc. Under fixed conditions, by this method, columbic oxide is reduced to the empiri caloxide $\text{Cb}_{20}\text{O}_{31}$, and can be titrated with permanganate.

The method of separation proposed by Weiss and Landecker§ will be discussed in the article immediately following this.

The low density of columbic oxide (4.552) as compared with the density of tantalic oxide (8.716) suggested that the composition of any mixture of the two could be deduced from its density, if the density of mixtures of known composition was first determined. The principle has been applied by Penfield and Ford|| to the estimation of the proportions of tantalic and columbic oxides in stibiotantalite, assuming that the density of mixtures of the oxides is a linear function of the composition.

* Archiv. des Sci. Phys. et Nat., 1866.

† Osborne, this Journal [3], xxx, 329, 1885.

‡ Metzger & Taylor, Zeitschr. anorg. Chem., lxii, 383, 1909.

§ Zeitschr. anorg. Chem., lxiv, 65, 1909.

|| This Journal [4], xxii, 61, 1906.

The problem consisted in preparing various known mixtures of the two oxides under definite conditions and determining the densities of the mixtures.

Methods and Errors.

We first investigated the method to be used to determine the density. The mixed oxides as they are obtained in analysis are very fine powders. After some preliminary work the following method for determining density was adopted. The ordinary form of bottle pycnometer of 10^{cc} capacity was used. The stopper was carefully ground to fit, using fine carborundum powder. The capacity was redetermined from time to time, but it remained nearly constant. The unweighed material was finely powdered and placed in a small beaker half full of water. The water was boiled hard for a half hour by passing an electric current through a fine spiral of platinum wire suspended in the water, the powder being stirred up a number of times during the operation. The water could not be boiled in a beaker over a flame on account of severe bumping, as the powder settles rapidly. The boiling can be accomplished over a flame, however, if a rough platinum dish is substituted for the beaker and the liquid stirred continually. The contents of the beaker were cooled, most of the water poured off, and the residue washed through a funnel into the pycnometer with boiled water. Any powder on the neck of the pycnometer was washed down and the pycnometer filled to overflowing. Any powder or air bubbles floating on the top were swept off with a glass rod. Air bubbles did not usually adhere to the sides, but were always looked for and removed with a wire if present. The pycnometer was placed in a tank of water and kept at 20° C. for twenty minutes. The stopper was then inserted, the top quickly wiped off, and the whole dried and weighed at once. The contents were transferred to a platinum dish, evaporated to dryness, and ignited finally over a blast for five minutes. In transferring the contents of the pycnometer to the dish it was found that all loss could be avoided if the pycnometer were inverted over the dish and shaken slightly till the powder left the bottom. By then bringing the mouth against the side of the dish the mixture will run out quietly. Two or three rinsings with water are necessary. The pycnometer usually contained a trace of oxide sticking to the sides, which might weigh as much as two milligrams. It was therefore dried at 120° C. and weighed to determine the small amount of oxide. This method gave results which were entirely satisfactory for our purpose. The average difference between duplicates in forty determinations of density amounted

to 0.22 per cent. This result includes several determinations in which the amount of material used was under one gram, which increased the percentage error considerably. When two grams or more of material were used, duplicates seldom disagreed by more than 0.15 per cent. To illustrate: the densities found for a mixture containing 90 per cent tantalic oxide were 8.103 and 8.078 when 1.5 grams were used. Upon repeating the experiment with 3.3 grams of material, the densities found were 8.090 and 8.092.

We next determined that the mixed oxides became constant in density after heating for an hour over the blast lamp. For this purpose a sample of the mixed oxides from a Branchville columbite was ignited over the blast lamp for an hour in a platinum crucible. The density was determined and the material then ignited for five-minute periods, a density determination being made after each ignition. The results were; 4.908, 4.908, 4.919, 4.921, 4.923, 4.912. The material was then heated an hour longer and the density redetermined, the results being 4.924 and 4.923. In these and the following determinations the ignition was accomplished in 30 gm. platinum crucibles over a fairly powerful blast lamp. The question whether different preparations of the oxides in the same proportions had the same specific gravity could only be answered by making a series of such determinations. Complete duplicate series of mixtures were not made on account of lack of material, but the results given in the table, which appears below, show what agreement was obtained in each case. The average difference in density between different preparations of oxides having the same composition was 1.1 per cent. This appears to be the greatest source of error in the determinations, and shows that the method of preparing the oxides must be fixed as definitely as possible.

The detailed method of preparing the mixed oxides in condition for specific gravity determination was as follows: About three grams of the oxides were fused in a platinum dish with six times their weight of acid potassium fluoride till the mass was just liquid. The fusion was dissolved in 200° of hot water in a platinum dish, adding a little hydrofluoric acid to obtain a clear solution. The solution was made alkaline with ammonia, and after allowing the precipitate to settle, filtered on a rubber funnel and washed well with water containing ammonia. The precipitate runs through the paper if pure water is used. The precipitate was redissolved in the platinum dish, using as little dilute hydrofluoric acid and water as possible and evaporated to dryness. Ten cubic centimeters of concentrated sulphuric acid were added in such a way that the residue was completely moistened. The liquid was evaporated

over asbestos till all hydrofluoric acid was expelled, stirring if there seemed to be danger of spattering. The residue was cooled, 200° of water added, and the solution made alkaline with ammonia, filtered, and the precipitate washed with dilute ammonia. The precipitate was transferred while moist to a 30 gram platinum crucible and ignited over a blast lamp for an hour. The residue was ground to a fine powder with water and was then ready for the density determination previously described. This method of preparing the oxides may appear longer than necessary, but we adopted it only after preliminary work had made it appear essential. Acid potassium fluoride was used in decomposing the oxides instead of potassium bisulphate because the latter does not render the oxides completely soluble in hydrofluoric acid if they have previously been ignited. This fusion with acid fluoride does not involve any loss of either columbium or tantalum by volatilization. To prove this, 1.3576 gms. of mixed columbic and tantalic oxides were subjected to the process outlined above and 1.3603 gms. were obtained. If the mixed oxides have not been ignited and are completely soluble in hydrofluoric acid, this may be used to dissolve them instead of acid potassium fluoride. The first precipitate with ammonia from hydrofluoric acid solution can not be ignited and used for density determination, as it contains fluorine after being ignited. Washing the precipitate with dilute ammonia will not remove all the fluorides.

Results.

In preparing the mixtures for density determinations, we were fortunate in obtaining very pure tantalum and columbium oxides. Dr. W. E. Ford supplied a sample of columbic oxide which had been given him by Prof. E. F. Smith. It had been prepared from the chloride and was exceedingly pure. Dr. Ford also supplied some tantalum oxide from Dr. W. R. Whitney of Schenectady, who stated that the material was considerably over 99 per cent pure. Dr. T. B. Osborne furnished us with considerable amounts of potassium tantalum and potassium columbium double fluorides which we recrystallized and converted into the oxides. The densities were as follows:

Columbic oxide	(Smith)	4.552
"	(Osborne)	4.564
Tantallic	(Whitney)	8.716
"	(Osborne)	8.683

In making the mixtures, it was assumed that Smith's and Whitney's oxides were pure and that Osborne's columbic oxide contained 0.61 per cent tantalic oxide and his tantalic oxide

0.32 per cent columbic oxide. These values were calculated from the densities. The original intention was to make mixtures of the oxides at intervals of ten per cent. Irregularity in the curve showing change in density with change in composition when there was over 60 per cent of tantalic oxide caused us to repeat some of the determinations in this region, as we suspected an error in the work. We were led to the conclusion that in the mixtures containing a moderate excess (65-85 per cent) of tantalic oxide, the densities are not as constant as when other proportions are present. The table and curve given below will make this clearer. All the results which were obtained upon known mixtures are tabulated below with one exception. This result was obviously in error as the density was not approximately related to the composition. In most cases, the density of one mixture of any given composition was determined. Where the curve as plotted from the table showed irregularities, duplicate mixtures were made and the results enclosed in brackets in the table. All densities are referred to water at 20°.

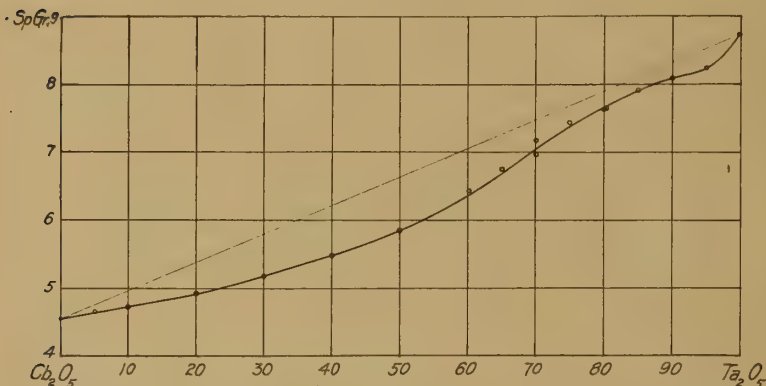
Composition % Ta ₂ O ₅	Specific gravity		Average specific gravity	
0	4.555	4.549		4.552
5	4.652	4.647		4.650
10	4.744	4.748		4.746
20	4.929	4.929		4.929
30	5.203	5.197		5.200
40	5.474	5.474		5.474
50	5.852	5.847		5.850
60	6.437	6.431		6.434
65	6.719	6.763	6.730	6.737
{ 70	7.189	7.170		
{ 70	6.958	6.992	7.008	6.981 }
75	7.431	7.452		7.441
{ 80	7.629	7.637		
{ 80	7.662	7.687		7.654
{ 85	7.885	7.925	7.963	
{ 85	8.01	7.99		7.961
{ 90	8.103	8.078	8.133	
{ 90	8.090	8.092		8.098
95	8.245	8.241		8.243
100	8.725	8.684	8.730	8.716

The average of the results in the table are plotted in the figure.

The curve has some interest from the standpoint of solid solutions. The fact that the points as plotted do not lie on a

straight line indicates that the oxides have formed a solid solution and not a mechanical mixture. The irregularities in the curve, which can hardly be due entirely to experimental error, suggest that the oxides are not soluble in each other in all proportions, but that tantalum oxide has taken up about 18 per cent of its weight of columbium oxide, and the latter

FIG. 1.



over twice its weight of tantalum oxide. The intermediate mixtures would then consist of mechanical mixtures of each oxide saturated with the other. In these mixtures the variations in densities of different mixtures of the same composition are greatest. Points on this part of the curve should lie on a straight line if the interpretation of these results as suggested is correct.

Analyses of Minerals by Density Method.

The analysis of a sample of stibiotantalite from the Brush collection was carried out using the indirect method for determining the relative proportion of tantalum and columbium oxides. The density of the sample was 6.80 and the weight four grams. The method used was as follows: Two one gram samples and a two gram sample were each dissolved in about 20^{cc} of hydrofluoric acid. Some white insoluble material remaining undissolved was filtered off and its weight deducted from that of the sample taken. The resulting weight was taken as that of stibiotantalite used for analysis. The solution containing an excess of hydrofluoric acid was diluted to 300^{cc} and hydrogen sulphide passed in until all antimony and bismuth were precipitated as sulphides. The precipitate was

filtered, washed with water, and treated several times with yellow ammonium sulphide. The insoluble residue of bismuth sulphide was dissolved in nitric acid, precipitated with ammonium carbonate, filtered, washed, ignited and weighed as Bi_2O_3 . The solution of antimony sulphide in ammonium sulphide was precipitated with sulphuric acid, (in the case of the two gram sample one tenth of the solution was used,) filtered in a porcelain Gooch crucible and washed with water. The crucible was supported in a triangle on a sand bath and covered with a 300^{cc} flask whose bottom had been removed. A glass tube and thermometer were fitted into the neck of the flask through a rubber stopper. The air in the flask was displaced by a rapid stream of carbon dioxide entering through the neck of the flask and escaping through the sand at the bottom. The temperature was raised to 240° and maintained for two hours, while carbon dioxide was passed in. At the end of this time all free sulphur had been removed from the Sb_2S_3 precipitate, as was shown by the weight remaining constant after further treatment. The crucible was allowed to cool in the atmosphere of carbon dioxide, its weight taken, and Sb_2S_3 calculated into terms of Sb_2O_3 .

The filtrate from the precipitation with hydrogen sulphide contained columbium and tantalum in solution in hydrofluoric acid. It was evaporated to dryness, moistened with concentrated sulphuric acid, and heated until all hydrofluoric acid was expelled. Water was added and the solution made alkaline with ammonia, filtered, the precipitate washed, ignited, and weighed. After heating over a blast lamp for an hour the density was determined. In experiments 2 and 3 the hydrofluoric acid solutions containing tantalum and columbium were united in order to obtain enough material for a reliable determination of density. The results of the analysis are as follows:

	1	2	3	Average
Sb_2O_3 -----	40.98	40.98	40.91	40.95
Bi_2O_3 -----	---	0.50	0.69	0.60
Ta_2O_5 -----	41.53	42.30	42.30	41.92
Cb_2O_5 -----	16.56	15.82	15.82	16.19
		99.60	99.72	99.66
Density of mixed oxides of Ta and Cb	7.191	7.282	7.282	7.236

$$\text{Ratio of } \frac{\text{Sb}_2\text{O}_3 + \text{Bi}_2\text{O}_3}{\text{Ta}_2\text{O}_5 + \text{Cb}_2\text{O}_5} = 0.92$$

The density method was also applied to the partial analysis of a Branchville columbite and for comparison tantalum and columbium were separated and determined by the Marignac method. The specimen contained no titanium. The oxides obtained in the course of analysis were soluble in hydrofluoric acid, so that preliminary fusion with acid fluoride was unnecessary. The solution was precipitated with ammonia, filtered, redissolved in hydrofluoric acid and evaporated with sulphuric acid, etc., as previously described. The results of the duplicate analysis are given in the following table:

Per cent $Ta_2O_5 +$ Cb_2O_5 in mineral	Density of mixed oxides	Per cent Ta_2O_5 in oxides by density method	Per cent Ta_2O_5 in oxides by Marignac method	Per cent oxides in mineral by density method		Per cent oxides in mineral by Marignac method	
				Ta_2O_5	Cb_2O_5	Ta_2O_5	Cb_2O_5
1. 78.77	4.957	21.0	18.74	16.54	62.23	14.43	63.68
2. 79.04	4.918	20.0	17.21	15.81	63.23	13.60	65.75

It will be seen that the results are approximately alike by the two methods, but we believe the results by the density method are more accurate and they are certainly much easier to obtain. The specific gravity of the columbic oxide from one Marignac separation was found to be 4.612 corresponding to 96 per cent of columbic oxide and 4 per cent tantalic oxide, showing that some tantalum went with the columbium. It is probable also that some columbium crystallized with the tantalum double fluoride but the amount of tantalic oxide was too small for a density determination.

The authors wish to express their thanks to Dr. W. E. Ford and Dr. T. B. Osborne for the tantalum and columbium oxides used in this investigation.

Sheffield Chemical Laboratory,
New Haven, Connecticut,
July, 1910.

ART. XLIV.—*Note on a Recent Method for Separating Tantalum and Columbium*; by H. W. FOOTE and R. W. LANGLEY.

A NEW method of separating tantalum from columbium was proposed recently by Weiss and Landecker.* This method consists essentially in fusing the mixed oxides with sodium carbonate containing a little nitrate and treating with hot water. Some tantalum, as sodium tantalate, remains insoluble and is removed by filtering and treated separately. The tantalum remaining in solution is precipitated by carbon dioxide. The authors state that if the conditions are properly adjusted, all the tantalum is precipitated, leaving columbium in solution. On the other hand, Rose† and Ostwald‡ state that both are completely precipitated by carbon dioxide from a sodium carbonate solution.

We have tried a considerable number of experiments following the directions given by Weiss and Landecker as closely as possible but varying certain conditions not defined by the authors. We were unable to make any satisfactory separation by this method. On the contrary, in every case nearly all the columbium precipitated with the tantalum. The authors state that a separation depends upon adjusting the amounts of reagents used, the method of fusion, and the concentration of the solution within narrow limits. These conditions, in our experiments, were adjusted to conform as closely as possible with the slightly indefinite directions given by the authors. The quantities of reagents and the concentration of solutions were also varied somewhat to effect a separation if possible. The method—taken from Weiss and Landecker—was as follows. The amounts of reagents used will be given in the table. About 0.3 gm. of a known mixture of tantalic and columbic oxides was fused with sodium carbonate over a blast till effervescence ceased. Sodium nitrate was added and the fusion continued about ten seconds. The fusion was treated with hot water on the steam bath for two hours and the insoluble residue filtered and washed with 5 per cent sodium bicarbonate solution. The filtrate, containing columbium and tantalum, was cooled and carbon dioxide passed in until no further precipitate formed. In the meantime, the insoluble sodium tantalate was boiled with dilute sulphuric acid and hydrogen dioxide to dissolve it. We were never successful in getting complete solution at this point. Sulphurous acid was added and the solution kept warm for two hours to reprecipitate the dissolved tantalum. The precipitate was filtered,

* Zeitschr. anorg. Chem., lxiv, 65, 1909.

† Handbuch analyt. Chem., 6th ed., ii, 339.

‡ Grundlinien anorg. Chem., ed. 1900, 726.

washed, ignited and weighed. The oxide precipitated with carbon dioxide, which should have been pure tantalic oxide, was filtered and the weight after ignition added to the weight of tantalic oxide already obtained.

The filtrate from the carbon dioxide precipitation was acidified with sulphuric acid, an excess of sulphurous acid added, the solution boiled and allowed to stand. The precipitate which should have contained all the columbium was filtered, washed, ignited and weighed. As a precaution ammonia was added to the filtrate to be sure that no columbium was left in solution.

The results of these experiments are tabulated below. They show that we obtained no separation in any case, but that columbium was almost quantitatively precipitated with the tantalum by carbon dioxide. The precipitate must have carried some alkali with it as the amount of tantalum and columbium oxides recovered was always apparently greater than the amount used.

The results of the experiments are tabulated below.

No.	Ta ₂ O ₅ taken (gms)	Cb ₂ O ₅ taken (gms)	Ta ₂ O ₅ found (gms)	Cb ₂ O ₅ found (gms)	Na ₂ CO ₃ used for fusion (gms)	NaNO ₃ used for fusion (gms)	Vol- ume when CO ₂ was passed in (cc)	Remarks.
1.	·2100	·0900	·3025	none	about 2 gms.	·1 gm.	600	A precipitate separated on standing over night before passing CO ₂ .
2.	·2129	·0913	·3219	·0117	·58	·05	250	
3.	·1975	·0846	·2903	·0125	1·2	·05	250	
4.	·2465	·0616	·3167	·0030	·6	·05	250	Precipitate with CO ₂ separated in 1 hour stopped CO ₂ in 1½ hours.
5.	·2362	·0591	·2974	·0056	1·2	·05	250	Fused mass when treated with water contained many crystalline plates.
6.	·2580	·0645	·3193	·0167	1·8	·05	250	
7.	·2546	·0637	·3220	·0087	1·8	·05	250	
8.	·2728	·0682	·3425	·0037	1·8	0·1	250	Precipitate with carbon dioxide became crystalline on boiling.
9.	·2838	·0710	·3654	trace	1·8	0·1	250	

The results have convinced us that the method in its present form is unreliable but it is possible that other conditions can be found which will permit a separation. If this could be done the method would be exceedingly valuable.

Sheffield Chemical Laboratory, New Haven, Connecticut.

ART. XLV.—*On the Symmetric Arrangement in the Elements of the Paleozoic Platform of North America*,* by
 RUDOLF RUEDEMANN.

WE wish to present certain facts indicating that the structural development of eastern North America has taken place in such a fashion that a notable symmetric arrangement of its elements has resulted.

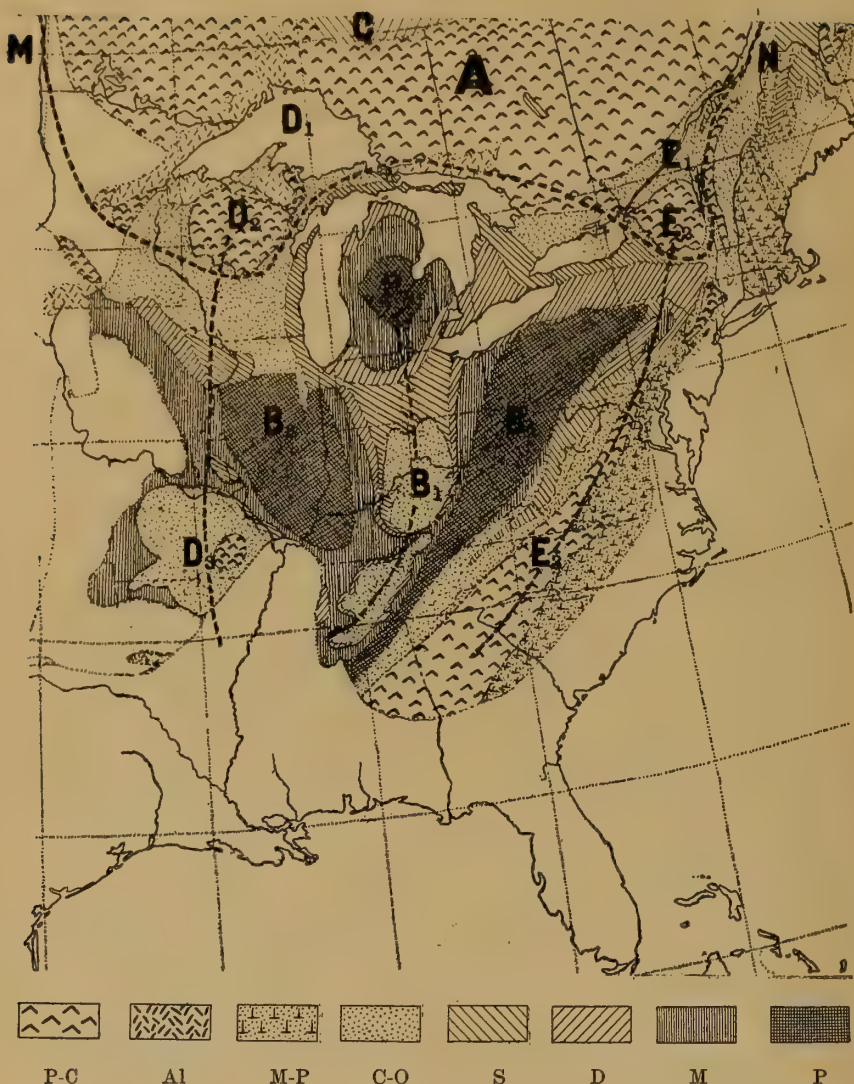
This arrangement becomes especially distinct when the large area of Paleozoic rocks extending from the Canadian protaxis southward is considered by itself. This area, which is roughly bounded on the west by a line connecting the head of Lake Superior with the Ozarks and on the east by a line inclosing the Adirondacks and Appalachia, we may for convenience term the *Paleozoic platform of North America*. It corresponds in its relation to the Canadian shield with that of the "Russian platform" of the European geologists to the Baltic shield. A glance at the geologic map of North America will show that this platform is a direct southward continuation of the Canadian shield or protaxis and bounded by southward converging lines that are direct continuations of the boundaries of that shield,† as described by Suess and Willis. In the west the platform, like the Canadian shield, is separated from the Rocky mountain area by the north-south transcontinental depression that extends from the Gulf of Mexico to the mouth of the Mackenzie river and is occupied by Cretaceous and Tertiary rocks.

In comparing the sketch map (fig. 1) with the diagram (fig. 2) in which separate shading brings out the elevated and depressed regions, it is seen that on either side of the Canadian shield or protaxis [A], there stand out, like cornerstones, two separate Precambrian areas, the Isle Wisconsin [D₂] and the Isle Adirondack [E₂] in quite symmetric positions. Each has its extension connecting it with the protaxis in symmetric position, that of the Isle Wisconsin being directed northeast (partly submerged by Lake Superior), that of the Isle Adirondack northwest. From each of these extensions there runs outward, along the margin of the shield, a deep depression, the Lake Superior basin [D₁] and the St. Lawrence basin [E₁]. The latter is less distinct through the disturbing influence of

* Condensed from N. Y. State Museum Bulletin 140, pp. 141-149, 1910.

† The Mesozoic and Cenozoic embayment of the Mississippi Valley is, in this discussion, left out of consideration, because of younger age; likewise the belt of Carboniferous rocks to the west and southwest of the Ozarks, that forms the outer slope of the western arm of the platform, roughly corresponding to the area of metamorphic rocks on the opposite slope of the other arm, and properly belonging to the transcontinental depression.

FIG. 1.



P-C, Precambrian. Al, Algonkian. M-P, Metamorphosed Paleozoic. C-O, Cambro-Ordovician. S, Silurian. D, Devonian. M, Mississippian. P, Pennsylvanian.

FIG. 1. GEOLOGICAL SKETCH MAP OF THE EASTERN UNITED STATES.

MN, southern boundary of Canadian shield, A. D₂ and E₂, the symmetric Isles Wisconsin and Adirondack. D₁ and E₁, the adjoining marginal depressions of the shield. D₂-D₃, guide line of western arm of platform; E₂-E₃, that of the eastern arm. D₃, Isle Ozark. E₃, Isle Appalachia. B₁-B₂, guide line of axis of eastern basin. B₁, Cincinnati geanticline. B₂, Michigan basin. B₃ and B₄, symmetric subbasins.

the Appalachian folding and probably much obscured by extensive overthrusting from the southeast along "Logan's line." The effect of Appalachian folding by crushing in one side of the symmetric structure here set forth, will be discussed more fully in another chapter (see p. 408).

From each of these cornerstones there extends southward, like an arm, a broad belt of Precambrian and early Paleozoic rocks, nearly the full length of the continent. The western arm can be traced by the great southward extension of the Precarboniferous rocks of Isle Wisconsin to near the neighborhood of Burlington, the Siluro-Devonian inlier along the Mississippi above its junction with the Missouri and the large Precambrian-Cambro-Silurian inlier or uplift of the Ozarks in Missouri and Arkansas* [D_2]. Its "Leitlinie" is shown in the thick broken line marked D_2 through D_3 . The eastern arm [E_2 - E_3] has been badly overridden, broken up and forced inward by the tangential pressure that has produced the Appalachian folds. It is, nevertheless, still easily recognized in the belt of Precambrian and Precarboniferous rocks, extending south and southwestward from New York as far as Alabama.

The two arms have later been somewhat disturbed and obscured, especially the western one, by the breaking down of certain portions south of Isle Wisconsin, where the Carboniferous has transgressed it, and the eastern one by the submergence of portions southeast of the Adirondacks and by extensive folding. In their original position the two arms may be conceived as approaching each other somewhat in the south, although not nearly so much as they do now, in consequence of the forcing inward of the eastern arm, for if the considerable shortening of the eastern basin indicated by the Appalachian folds is taken into account and the basin spread out to its original width, the eastern arm would probably take a position fully corresponding to that of the western.

These two arms bound a large basin, the "Paleozoic eastern basin," now occupied by the basin of Ohio and the Great Lakes. In the middle of this an elongated low elevation formed, now indicated by the Cincinnati and Nashville "uplift."

The axial position of this uplift (see line B_2 - B_3 , fig. 1) suggests that it may partake of the nature of the "geanticlinal median"† that according to Haug‡ forms along the median

* The Ouachita mountains in Arkansas probably represent, according to Dr. Ulrich's description [in Preliminary List of Papers, Geol. Soc. Am., 21 Meet. 1908, p. 21] and as already indicated by their strike, a different element and will, for this reason, be left out of the discussion for the present.

† Dana clearly recognized this uplift as a geanticline.

‡ Haug, Émile, Bull. Soc. Géol. Fr. (3), xxviii, 617, 1900; and *Traité de Géologie* I, 164, 1907.

line of a geosyncline preparatory to more extensive folding. The southern portion of the uplift which, according to its normal position to the basin and the Precambrian arms, should

FIG. 2.

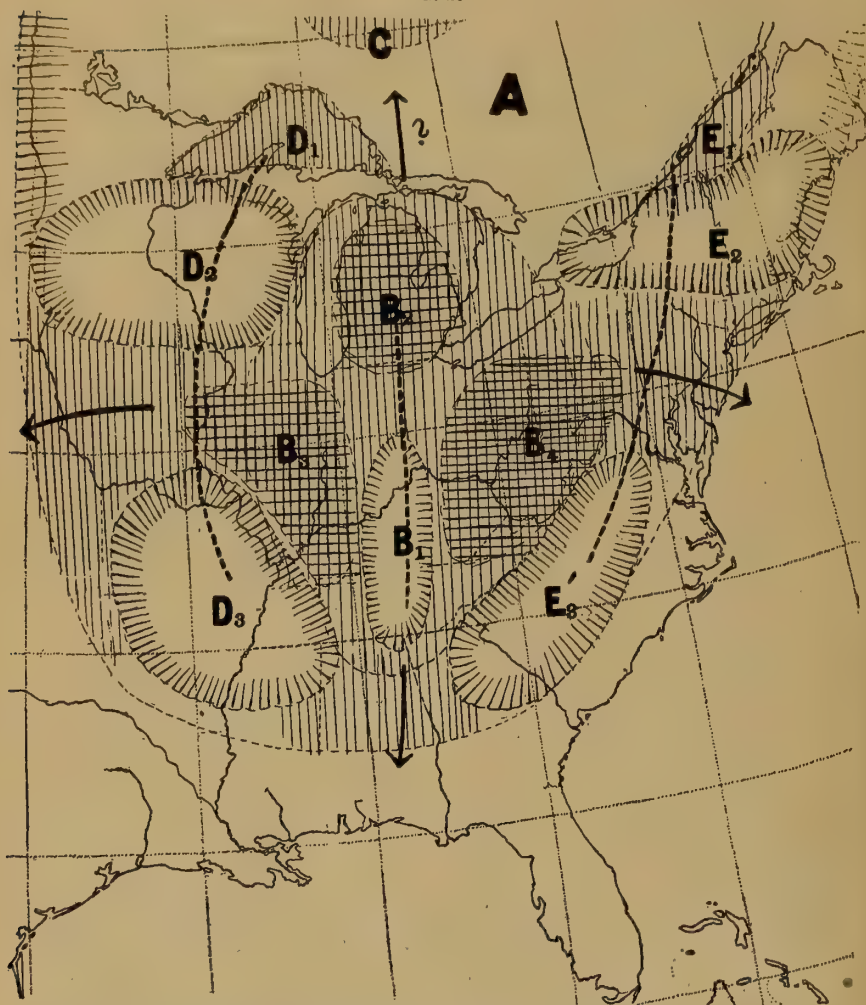


FIG. 2. Diagram to show events on southern slope of North America still without interference of Atlantic pressure. Lettering as on figure 1. Arrows indicate main outlets of basin B.

extend due south, has been affected by the Appalachian folding and twisted into a southwest direction. As a result of the

warping of the axis of the basin, two separate symmetric basins have been formed,* one, the Eastern Interior, and the other, the East Central basin. On account of the approach of the Precambrian arms in the south, these basins do not extend north and south, but extend symmetrically to northwest and northeast. The Ohio river from the Pennsylvania to the West Virginia line flows along the axis of the eastern basin.

The northern portion of the Paleozoic platform that lies to the north of the Cincinnati geanticline assumed the aspect of a separate subcircular basin, typically indicated by the Michigan coal field and the locations of Lake Michigan and Lake Huron. It also lies symmetric to the whole arrangement and with the Cincinnati uplift it is on the line of symmetry. It is possible that this Michigan basin, instead of being an independent depression, originated from the same warping force as the Cincinnati uplift, being the result of a longitudinal oscillation of the axis of the same geanticline, comparable to those more intensive longitudinal oscillations of the axes, which have been observed in some of the Alpine folds (see Haug, *Traité*, p. 211). The Canadian geologists, however, have claimed to find the influence of the Cincinnati uplift extending from the west end of Lake Erie farther north to Lake Huron. In this case it would seem that the Atlantic pressure had affected the entire extent of the uplift [see p. 408] giving it a direction subparallel to the Appalachian folds, and the Michigan basin would have to be considered as independent of the Cincinnati uplift, a view distinctly not supported by the general distribution of the formations around the basin.

The development of these symmetric structures may have taken place as shown in figures 1 and 2. In figure 1 the Canadian shield A and its Paleozoic platform are separated by the line M-N. First, then, an extensive depression affected the middle portion of the platform producing the Paleozoic eastern basin, fig. 2, B₂, B₄, and leaving two long embracing arms standing, the western one D₁₋₃ and the eastern one E₁₋₃.

The following changes took place in the two arms and in the inclosed basin. The arms were broken up, with the result that on either side two principal isles, Isle Wisconsin [D₂] and Isle Ozark [D₃], Isle Adirondack [E₂] and Isle Appalachia [E₃] were formed. These isles are distinctly paired. On either side between the Canadian shield and the first isle a depression formed, the Lake Superior basin [D₁] and the St. Lawrence

* Dana [Areas of Continental Progress in North America, etc. Bull. Geol. Soc. Am., i, 41, 1890], recognizing the importance of the regions of shallow seas represented by the Cincinnati uplift and the Precambrian region of Missouri as regards rock-making, has distinguished these basins by the terms here used.

basin [E₁], and other depressions between the first and second isles.

In the Paleozoic eastern basin a broad low anticline, the Cincinnati-Nashville parma [B₁], arose*; exactly in the axial line of the depression and in continuation of this line of elevation the northern part of the basin sank down into an axial basin, the Michigan subbasin [B₂]. On either side of the parma, between the latter and the Precambrian arms, two basins, the East Central [B₃] and the Eastern Interior basin [B₄], were formed, in such an arrangement that they converge southward and are exactly symmetrical to the axial line of the eastern basin.

The stress from the sub-Atlantic pressure, the cause of the Appalachian folding and overthrusting crushed or crumbled this symmetric structure from the southeast, its influence being felt in the whole eastern portion of the area. Its effect is seen by a comparison of figures 1 and 2. Following Clappole's earlier estimates, Willis (Bull. Geol. Soc. Am., xviii, 404, 1907) remarks that "it is a moderate statement to say that during the Appalachian revolution that portion of the continent southeast of the Cumberland Plateau rim moved northwestward at least 50 miles."

On account of its oblique direction to the north-south axis of the Paleozoic eastern basin, the stress reaches deepest into the latter in the south, where it has clearly turned the Nashville portion of the Cincinnati-Nashville parma aside. It further lengthened the Eastern Interior basin, and extended it into southeastern New York, or considerably farther north than the opposite East Central basin. Moreover, it may have produced secondary depressions east of the Michigan basin, which have finally found expression in Lakes Erie and Ontario. The principal facts suggesting the latter view are the general parallelism of these lake basins with that portion of the Appalachian folds southeast of them† whence the push came. It should, however, in this connection be taken into account that it can have been but the last stages of Appalachian folding that produced the gentle down-warping of these basins, since the outwardly convex strike of the earlier Paleozoic formations (best seen at the west end of Lake Ontario) shows that this was an elevated region until at least Devonian time. It is, therefore, quite possible that these depressions are the counterparts of the late (early Tertiary)

* Suess has termed such broad warpings "parmas."

† By drawing a straight line connecting the folds from the Tennessee-Virginia line to the Pennsylvania-New Jersey line, one obtains a line that indicates the general direction of this portion of the folds, and that line is parallel to the two lake basins.

domelike warpings in western Pennsylvania* and southern New York, to which their longitudinal direction clearly corresponds.

The joining of the Appalachian folds that die out in southern New York by a new north-south system of folds in eastern New York, brings the folded region close against the Adirondack isle and produces another depressed "Vorland," the Champlain basin. The Ottawa-Montreal basin that corresponds in its position and also in its form, in surrounding the north side of the Adirondack isle, to the Lake Superior basin, has also been much encroached upon by the westward pressure of the folded region and no doubt to no little amount by extensive overthrust.

It will be seen that with the conception here presented of the geologic development of the eastern United States, the Great Lakes fall, by the first impetus to the formation of their basins—omitting the later accessory agencies, as glaciation and pre-glacial drainage-lines—into three groups, viz :

(a) Lake Superior, originating from the breaking down of one of the arms of the Canadian shield.†

(b) Lake Michigan and Lake Huron. Their location and form correspond to the Michigan basin, where they roughly follow the Devonian belts.

(c) Lake Erie and Lake Ontario, either depressions originating from the action of the Atlantic tangential pressure, or counterparts of later warpings in the upper Ohio basin and western New York.

We have thus far left out of consideration the Appalachian basin or "geosyncline" which occupies a narrow strip on the west side of Appalachia and is continued northward through New York and Vermont into Canada. It has later become the site of the Appalachian folds. Ulrich and Schuchert‡ have clearly shown that this basin became early subdivided by longitudinal and transverse barriers into a number of smaller basins. In their directions these barriers foreshadow the later, more intensive Appalachian folding, and are early indications of the influence of the pressure acting from the Atlantic basin upon and through Appalachia. It is certain that the Appalachian basin itself which became the site of the intense folding resulted from the Atlantic pressure upon Appalachia, due to suboceanic spread. It is therefore a foreign element, so to say, in the geologic history of the Paleozoic platform, which, however, has strongly obscured the original symmetry of the latter. While all changes here noted on the platform are of

* See Campbell, M. R., Bull. Geol. Soc. Am., xiv, 277, 1903.

† The Lake Superior basin clearly antedates all the others, at least with its western arm, which rests in Algonkian rocks that indicate a very early depression in the Canadian shield.

‡ N. Y. State Mus. Bull., lii, 633, 1901.

epirogenic character, the Appalachian folds are an orogenic feature.

While in general the isles have emerged in Paleozoic times and the basins have been submerged, there have been continuous changes in the amount of emergence and submergence. This fact becomes especially manifest through Professor Schuchert's paleogeographic maps,* and it is probable that these subsidences and elevations took place in rhythmic pulsations.

With all these continuous changes, however, the sum total of the elevations of Isle Wisconsin, Isle Adirondack, Ozarkia and Appalachia has been greater than that of the depressions, and they represent, therefore, positive elements of the continent in the sense used by Willis,† while the depressions are negative elements in which, however, in some zones, as in the Cincinnati uplift, the algebraic sum of the unconformities and sediments may approach zero. The most conspicuous negative element is the Appalachian basin with its immense sedimentation.

The symmetry of arrangement of the platform is likewise but a surplus of symmetric features in the general structure over many asymmetric details in the different stages through which the platform has passed. This again is well shown by the charts of Professor Schuchert. It will be seen that at times the Nashville uplift was joined to Appalachia, and the Eastern Interior basin moved northward, while the East Central basin was divided by a secondary peninsula (Kankakee) and Ozarkia joined to a vast western tract. But at the same time the two arms of the platform with their northern isles Wisconsin and Adirondack (as peninsulas) and the southern land bodies of Ozarkia and Appalachia remained distinct elements, and likewise the Mediterranean-like basin remained defined in its general outline.

The main outlets from the Paleozoic sea (see fig. 2) passed eastward between Isle Adirondack and Appalachia and westward between Isle Wisconsin and the Ozark uplift and southward between Ozarkia and Appalachia. The Wisconsin and Adirondack isles have apparently been frequently attached to the protaxis. This becomes especially manifest in the case of the Adirondack isle, where the Beekmantown, Pamela, Chazy, Lowville and probably also Black River formations do not cross the connecting Frontenac axis. The St. Lawrence depression, however, frequently became an important highway of migration (as in Beekmantown, Onondaga and Hamilton times) through its southward connection, by different straits, at different times with depressions between the Isle Adirondack and Appalachia (see *p. e.* Schuchert's map of Onondaga time).

* Bull. Geol. Soc. Amer., xx, 427-606, 1910.

† Willis, Bailey, Bull. Geol. Soc. Amer., xviii, 389, 1907.

There are facts available that indicate approximately the time when the symmetric arrangement of the Paleozoic platform took place. As we have noted before, Algonkian sedimentation took place around Lake Superior (see fig. 1), but aside from this somewhat independent depression, the whole platform was, according to Walcott's investigation,* above sea level until Upper Cambrian time, with the exception of the Appalachian geosyncline. The relation of the Upper Cambrian deposits to the Isles Wisconsin and Adirondack would indicate that in this period the separation of the Paleozoic eastern basin and of the inclosing arms took place and probably also the beginning of the breaking up of the arms. The Isles Wisconsin and Adirondack, Ozarkia and Appalachia have remained above the sea since the end of the Lower Silurian. In Upper Silurian time the Cincinnati parma had become a prominent feature, although the Cincinnati and Nashville parts of the same were again separated repeatedly, as in Hamilton and Mississippian times, by the submergence of the middle part. In Carboniferous (Mississippian and Pennsylvanian) times all the subdivisions of the platform distinguished above were fully developed. Since then the platform has remained land, with the exception of the Mesozoic Mississippi embayment.

Summary.

The writer endeavors to point out:

1. That the Paleozoic platform of North America extending south from the Canadian shield forms, together with the latter, a structural element of the continent, that is similar in outline to the latter.
2. That the Paleozoic platform exhibits a symmetric arrangement of its parts. This symmetric arrangement consists in the presence of a median basin (Paleozoic eastern basin) that is flanked on both sides by broad elevations, extending southward from the Isles Wisconsin and Adirondack which possess symmetric positions with reference to the Canadian shield. Ozarkia and Appalachia, the two remaining portions of elevations, hold like symmetric positions.
3. The axial line of the Paleozoic eastern basin is occupied by the Cincinnati-Nashville parma and the Michigan subbasin. The former divides the Paleozoic eastern basin into two similar and symmetric basins, the Eastern Interior and East Central basins.
4. The disturbing factor has been the Atlantic pressure, which pushed the eastern arm in and produced the Appalachian basin folds, its effect reaching as far as the Nashville uplift.

* See Walcott, U. S. Geol. Survey Bull., lxxxi, pl. 2, 3, 1891.

SCIENTIFIC INTELLIGENCE.

I. CHEMISTRY AND PHYSICS.

1. *The Behavior of Metallic Copper towards Gases*.—SIEVERTS and KRUMBHAR have made an elaborate study of the solubility of several common gases in solid and liquid metallic copper. The behavior of oxygen is well known; it dissolves in molten copper in the form of cuprous oxide, and upon solidification it is not given off, even in an atmosphere free from oxygen. Nitrogen, carbon dioxide and carbon monoxide are not absorbed either by the solid or molten metal. Hydrogen is absorbed by solid copper at elevated temperatures. The diffusion of this gas through a thin copper tube was observed at 650° C. and it was found that the rapidity of diffusion and the solubility increases with the temperature. Above the melting point of copper the solubility of hydrogen in the metal becomes greater, and it increases again with the temperature, at least as far as 1500° C., the temperature to which the measurements were carried. At constant temperature the solubility of hydrogen in the molten copper varies according to the square root of the pressure. Solid copper absorbs no sulphur dioxide, but the liquid metal dissolves it abundantly. This solubility, at constant pressure, increases with the temperature from the melting point to 1500° C., becoming more than twice as great at the latter temperature. The solubility of sulphur dioxide, like that of hydrogen, in molten copper, varies according to the square root of the pressure. The agreement of hydrogen and sulphur dioxide in regard to their pressure solubility appears to contradict a theory advanced by van't Hoff to the effect that this peculiar pressure relation is due to a change from the molecular (H_2) to the atomic form upon solution, for the SO_2 , with three atoms in it, should not show the same relation. The increase in solubility of these gases with the temperature shows that their dissolving must take place with the absorption of heat, and this behavior seems to be general with solutions of gases in metals, although it has been observed very rarely in the solutions of gases in water. — *Zeitschr. physikal. Chem.*, lxxiv, 277.

H. L. W.

2. *The Diffusion of Crude Petroleum through Fuller's Earth*.—The fact that natural oils have been changed in composition by percolation through porous strata in the earth is now well recognized, since various experiments have shown that such fractionation may be carried out by artificial means. GILPIN and BRANSKY have recently described an extensive series of experiments with natural products and mixtures, using tubes packed with fuller's earth, and have confirmed this view of an important cause of the variations in composition of natural oils. They reach

the following conclusions in regard to diffusion upward through fuller's earth: 1. With a solution of benzine and paraffin oil, the benzine tends to collect in the lower part, and the paraffin oil in the upper part. 2. When crude petroleum is used, the oil that is displaced by water from the earth of the upper part has a lower specific gravity than that obtained in the same way from the lower part. 3. As the fractionation proceeds the range of specific gravity in succeeding fractions becomes smaller, indicating a tendency towards the production of mixtures which will diffuse without change. 4. In the fractionation of petroleum the lighter portions toward the top become gradually freer from unsaturated hydrocarbons and sulphur compounds. 5. Fuller's earth tends to retain the unsaturated hydrocarbons and the sulphur compounds, thus exercising a selective action upon the oil.—*Amer. Chem. Jour.*, xliv, 251.

H. L. W.

3. *Vacuum-tight Seals between Iron and Glass.*—It has been found by H. J. S. SAND that an iron wire sealed into glass may be made vacuum-tight by passing over the protruding wire, while the glass is still hot, a small piece of heated steel tubing and pushing this into the soft glass for a distance of a few millimeters. After cooling, the outer end of the tube is soldered to the wire. The explanation is given that the tube by its contraction compresses the glass within it and thus forms an effective seal. Tubes into which iron wires 1^{mm} diameter have been sealed in this manner have been exhausted to a cathode-ray vacuum and have maintained this for four months, up to the time of publication. It is not yet certain that the seals will have a practical importance in replacing platinum in the case of rapid wholesale manufacture. The author points out that, as far as he is aware, previous proposals to replace platinum for this purpose by iron-nickel alloys or thin, flat strips of copper have met with little success. It is to be hoped that the method under consideration or some other satisfactory process will soon be devised for the saving of platinum.—*Chem. News*, cii, 166.

H. L. W.

4. *The Structure of Meteoric Alloys.*—W. GUERTLER has discussed the structure of the iron-nickel meteorites from the point of view of modern metallography. Fränkel and Tiemann have previously reached the conclusion that the meteoric structure is metastable, since upon heating to 800° C. the material then behaves like artificial alloys, and shows no evidence of again attaining the well-known meteoric structure. Guertler's conclusion, which appears to be well sustained by his arguments, is, in short, that the meteoric structure is a stable one requiring an exceedingly long time for its formation. He believes that the temperature at which the change takes place is comparatively low and consequently very slow, and that there is no need to assume a metastable condition in the natural alloy.—*Zeitschr. physikal. Chem.*, lxxiv, 428.

H. L. W.

5. *Liquefaction of Helium.*—H. KAMERLINGH ONNES describes his method of liquefying helium and states its properties. The

point of ebullition of liquid helium is 4.3 absolute degrees. When this value is corrected for proper transference of helium to the absolute scale, the point of ebullition will probably be 4.5 . The pressure at the triple point is less than 1^{cm} of mercury. According to corresponding states, the temperature corresponding to the pressure of 1^{cm} is in the neighborhood of 3 absolute degrees and, nevertheless, the liquid is still perfectly mobile. Liquid helium has a very low density, 0.15 , which leads to a provisional value of b of 0.0007 . This gives for the critical pressure an approximate value of 2 or 3 atmospheres. At the point of normal ebullition the ratio of the density of the vapor to that of the liquid is in the neighborhood of $\frac{1}{11}$. This indicates a critical temperature hardly higher than 5 absolute degrees, and a critical pressure a little greater than 2.3 atmospheres. The provisional value of the coefficient of pressure a is 0.00005 , the smallest value of a relative to different bodies, and lower than that of hydrogen, which for a long time was considered 0 .—*Communications from the Physical Laboratory of Leyden*, No. 108. J. T.

6. *Photoelectric Fatigue*.—Dr. H. STANLEY ALLEN reviews the theories in regard to this fatigue and thus summarizes them:—

- (1) A chemical change, such as oxidation of the surface.
- (2) A physical change of the metal itself, as, for example, roughening of the surface.
- (3) An electrical change in the formation of an electrical double layer (Lenard).
- (4) A disintegration of the metal due to the expulsion of electrons by light (Ramsay and Spencer).
- (5) A change in the surface film of gas or in the gas occluded in the metal (Hallwachs).

Dr. Allen concludes from his own experiments that we must look to the gaseous films on the surface of the metals for the explanation of the chief effects of photoelectric fatigue.—*Phil. Mag.*, Oct. 1910, 564–573. J. T.

7. *A New Radiant Emission from the Spark*.—Professor R. W. WOOD shields the light of a spark from the eye by placing the spark behind a vertical strip of metal. No illumination is seen by the eye, but a photographic plate shows an actinic effect in the air surrounding the spark. The emission is absorbed by oxygen, and may be analogous to “Entladungsstrahlen.”—*Phil. Mag.*, Oct. 1910, 707–712. J. T.

8. *Sterilization by Ultra-Violet Rays*.—At first sight it would seem that ultra-violet rays would be absorbed to so great an extent by liquids that bacilli could not be reached at any depth. A millimeter thickness of water absorbs completely waves below 1800 . M. BILLON DAGUERRE, however, has discovered that the ultra-violet rays exert remarkable sterilizing effect on water. It seems possible that it may be a surface effect which is transmitted from bacilli to bacilli, for the light certainly has little penetrating power. The sterilizing action appears to be confined to clear water; impurities, suspended particles and colloids arrest

it. M. Billon Daguerre places a mercury vapor lamp in a tube through which the water circulates.—*La Revue Electrique*, May 15. J. T.

9. *International Congress of Radiology and Electricity*.—The second International Congress of Radiology and Electricity was held at Brussels, September 13–15 inclusive, 1910, the first congress having been held at Liège in 1905. The attendance reached nearly five hundred, and a very considerable proportion of the active workers in radio-activity and electronics were present at the various meetings. The formal ceremonies opened with a reception at the Bourse on the evening of the 12th, and the work of the Congress began on the following morning at a meeting held in one of the buildings on the grounds of the Exposition, where the presidential address was delivered by Professor de Heen, and various matters connected with the organization of the congress were arranged. On the afternoon of that day the members reassembled at the University and engaged in an interesting discussion in regard to standards and nomenclature. Attention was called by Professor Rutherford to the present importance of adopting a uniform standard for radio-active substances, and he pointed out that during the past year the standard specimens of radium salts employed in the leading laboratories of different countries had been compared under his direction and had been found to exhibit a marked lack of agreement. He was, therefore, convinced that for the successful development of the quantitative study of radio-active magnitudes the adoption of a uniform radium standard which could be accepted by all was highly desirable. Mme. Curie also spoke approvingly in regard to this proposal, which was heartily supported by all present at the meeting, and it was finally voted that a committee, the members to be appointed by Professor Rutherford and Mme. Curie, should be formed, and that this committee should consider the special needs and determine the conditions under which a suitable standard should be prepared and preserved. The matter of nomenclature was also briefly considered and it was generally agreed that at present there was nothing to be gained by the adoption of a more systematic nomenclature, as has been suggested by some, the present system being quite as satisfactory in all respects as any other which had been as yet proposed. The meeting then listened to an account by Mme. Curie of her recent interesting experiments of isolation of metallic radium. A number of other papers were also presented. On the following days the congress met in different sections for the reading of papers, of which a large number were presented on different subjects relating to radiology and electricity. These will be published later in the transactions of the Congress. Among the many pleasant features of the meeting were the reception at the town hall by the Municipality, and the admirable performance to which members were invited at the Théâtre Royal de la Monnaie. At the last meeting a committee, with members from different countries, was

appointed to have charge of the next congress, which there is reason for believing may be held within the next year or two. The committee appointed to have charge of the standards consisted of Mme. Curie and M. Debiérne for France, Professors Rutherford and Soddy for Great Britain, Professor Geitel and Dr. Hahn for Germany, Professors St. Meyer and von Schweidler for Austria, Professor Boltwood for the United States and Professor Eve for Canada.

The Standards committee reported at the last meeting of the Congress, and its recommendations were adopted. They were substantially as follows:

1. Mme. Curie has kindly agreed for the purposes of the standard to prepare a quantity of the purest obtainable anhydrous radium chloride containing about 20 milligrams of radium (element).

2. When the committee have reimbursed Mme. Curie for the cost of the Radium Standard, this will come under the control of the committee and will be used only for the measurement and comparison of secondary standards by means of the γ -rays. The original standard is to be suitably preserved and deposited in Paris.

3. Through the committee, and at their discretion, national scientific laboratories and bureaus of standards willing to pay the costs are to be provided with certified secondary standards.

4. By such methods as, after due consideration, meet with the approval of the committee, smaller subsidiary standards are to be prepared for distribution.

5. As radium emanation is now so generally used in scientific investigations, the committee consider the adoption of a unit for the measurement of the amounts of radium emanation desirable. The committee recommend that the name "Curie" be given to the quantity or mass of emanation in equilibrium with one gram of radium (element). The milli-curie would thus be the amount of emanation in equilibrium with one milligram of radium.

6. The question of proposing special names for units of measurement of minute quantities of radium and its emanation is under consideration, but no definite conclusions have as yet been reached.

7. As some members of the committee are not present at the Brussels Congress, and as it has not been possible to obtain information as to their views on these questions, the recommendations here made are not necessarily final. The committee reserves the power to modify them if on further consideration this appears to be desirable.

The preparation of a standard of pure radium salt is now assured. The advantages of having such a standard with which material used for various scientific investigations in different parts of the world can be compared is apparent, and it will also be extremely useful to have a definite standard, on the basis of which quantities of radium salts to be sold or purchased can

be measured. In the past great difficulties have been encountered in conducting commercial transactions involving radium salts, as, lacking any definite and accepted standard of quality, some dealers have been in the habit of selling as pure radium salts material of distinctly inferior quality. As the value of radium salts sold in the United States up to the present is probably considerably in excess of five hundred thousand dollars, the importance of having a definite and reliable check on the purity and strength of these preparations is most essential. The plan of the committee, known as the International Radium Standards committee, is to obtain the funds to cover the cost of the primary standard either through the governments or the scientific societies of the countries represented on the committee, or possibly through the coöperation of the International Bureau of Standards at Paris, where it is planned to ultimately deposit the Primary Standard. The committee sincerely desire the coöperation and assistance of all interested in the matter of the preparation of the present standard and communications in regard to this matter should be addressed to the Secretary of the Committee, Prof. Stefan Meyer, Institut für Radiumforschung, Waisenhausgasse 3, Vienna IX, Austria.

B. B. BOLTWOOD.

II. GEOLOGY AND NATURAL HISTORY.

1. *Publications of the United States Geological Survey*; GEORGE OTIS SMITH, Director.—Recent publications of the U. S. Geological Survey are noted in the following list (continued from vol. xxix, p. 363):

FOLIO, No. 171. Engineer Mountain Folio: Colorado; by WHITMAN CROSS and ALLEN D. HOLE. Pp. 13, with 3 colored maps and 15 figures.

BULLETINS.—No. 381. Contributions to Economic Geology, 1908. Part II—Mineral Fuels. MARIUS R. CAMPBELL, geologist in charge. Pp. 559, with 24 plates and 15 figures.

No. 419. Analyses of Rocks and Minerals from the Laboratory of the United States Geological Survey, 1880–1908; tabulated by F. W. Clarke, chief chemist. Pp. 323.

No. 425. The Explosibility of Coal Dust, by GEORGE S. RICE, with chapters by J. C. W. FRAZER, AXEL LARSEN, FRANK HAAS, and CARL SCHOLZ. Pp. 186, with 14 plates and 28 figures.

No. 426. Granites of the Southeastern Atlantic States, by THOMAS LEONARD WATSON. Pp. 282, with 27 plates and 20 figures.

No. 427. Manganese Deposits of the United States, with Sections on Foreign Deposits, Chemistry, and Uses; by EDMUND CECIL HARDER. Pp. 298, with 2 plates and 33 figures.

No. 429. Oil and Gas in Louisiana, with a brief Summary of their Occurrence in adjacent States; by G. D. HARRIS. Pp. 192, with 22 plates and 21 figures.

No. 430. Contributions to Economic Geology (Short Papers and Preliminary Reports), 1909. Several advance chapters have been issued, viz., A, on Gold and Silver; C, Lead and Zinc; D, Rare Metals; F, Structural Materials; G, Mineral Paints; H, Phosphate; J, Miscellaneous Nonmetallic Products; I, Saliness.

No. 432. Some Ore Deposits in Maine and the Milan Mine, New Hampshire; by WILLIAM H. EMMONS. Pp. 62, with 3 plates and 23 figures.

No. 434. Results of Spirit Leveling in Delaware, District of Columbia, Maryland, and Virginia, 1896 to 1909, inclusive. R. B. MARSHALL, chief geographer. Work done in coöperation with the State of Maryland during the entire period, and with the State of Virginia in part of 1908. Pp. 74.

No. 435. A Reconnaissance of Parts of New Mexico and Northern Arizona; by N. H. DARTON. Pp. 88, with 17 plates and 8 figures.

No. 437. Results of Spirit Leveling in Maine, New Hampshire, and Vermont, 1896 to 1909, inclusive. R. B. MARSHALL, chief geographer. Work done in coöperation with the State of Maine, during 1899, inclusive. Pp. 59.

No. 442-A. The Mining Industry in 1909, and Alaska Coal and its Utilization; by ALFRED H. BROOKS. Advance chapter, pp. 1-84.

No. 444. Bibliography of North American Geology for 1909, with Subject Index; by JOHN M. NICKLES. Pp. 174.

WATER SUPPLY PAPERS.—No. 237. The quality of the Surface Waters of California; by WALTON VAN WINKLE and FREDERICK M. EATON. Pp. 142 with one plate.

No. 240. Geology and Water Resources of the San Luis Valley, Colorado; by C. E. SIEBENTHAL. Pp. 128, with 13 plates and 15 figures.

Nos. 246, 247, 249, 250, 251. Surface Water Supply of the United States 1907-8. Prepared under the Direction of M. O. LEIGHTON.—No. 246. Part VI. Missouri River Basin; by ROBERT FOLLANSBEE and J. E. STEWART. Pp. 311, with 13 plates and 2 figures.—No. 247. Part VII. Lower Mississippi Basin; by W. B. FREEMAN, W. A. LAMB, and R. H. BOLSTER. Pp. 124, with 2 plates and 2 figures.—No. 249. Part IX. Colorado River Basin; by W. B. FREEMAN and R. H. BOLSTER. Pp. 206, with 10 plates.—No. 250. Part X. The Great Basin; by E. C. LA RUE and F. F. HENSHAW. Pp. 151, with 7 plates and one figure.—No. 251. Part XI. California; by W. B. CLAPP and W. F. MARTIN. Pp. 363, with 7 plates and one figure.

No. 253. Water Power of the Cascade Range. Part I. Southern Washington; by JOHN C. STEVENS. Prepared in coöperation with the State of Washington. Pp. 94, with 21 plates and 3 figures.

No. 255. Underground Waters for Farm Use; by MYRON L. FULLER. Pp. 58, with 17 plates and 27 figures.

No. 260. Preliminary Report of the Ground Water of Estancia Valley, New Mexico; by OSCAR E. MEINZER. Pp. 33.

2. *Federal Bureau of Mines*; JOSEPH A. HOLMES, Director. Bulletin I. The Volatile Matter of Coal; by HORACE C. PORTER and F. K. OVITZ. Pp. 56, with 20 tables and 9 figures.—This is the first independent publication of the newly established Federal Bureau of Mines (see v. xxx, p. 292). The work here detailed is now centered in the experiment station at Pittsburg, Penn., and had its beginning in investigations carried on at the coal-testing plant erected at St. Louis in 1904 in connection with the Louisiana Purchase Exposition. The authors state that "The investigation has already shown that the volatile content of different coals differs greatly in character. The volatile matter of the younger coals found in the West includes a large proportion of carbon dioxide, carbon monoxide, and water, and a correspondingly small proportion of hydrocarbons and tarry vapors. The older bituminous coals of the Appalachian region yield volatile matter containing large amounts of tarry vapors and hydrocarbons, difficult to burn completely without considerable excess of air and a high temperature. Coal of the western type, moreover, gives up its volatile matter more easily at moderate and low temperatures than that of the other type. The volatile matter produced at medium and low temperatures is rich in higher hydrocarbons of the methane type, such as ethane and propane, which contain a larger portion of carbon than is present in methane." The results are shown to have important economic applications of interest to engineers and mechanics in a variety of fields. Copies of the bulletin may be obtained by applying to the Director of the Bureau of Mines at Washington.

3. *Cambrian Geology and Paleontology No. 6—Olenellus and other Genera of the Mesonacidae*; by CHARLES D. WALCOTT (Smithsonian Miscel. Coll.), 53, 1910, pp. 231-422, pls. 23-44.—Our knowledge of the large and diagnostic Lower Cambrian trilobites is here greatly extended and made easily comprehensible through an abundance of most excellent illustrations. Of these trilobites there are in America and Europe 33 (16 new) species distributed in the following genera: *Nevadia* new (1), *Mesonacis* (2 European, 1 American), *Elliptocephala* (1), *Callavia* (5 European, 2 American), *Holmia* (2 European, 1? American), *Wanneria* new (3), *Pædeumias* new (1), *Olenellus* (3 European, 9 American), *Peachella* new (1), *Olenelloides* (1 European). All of the genera (with one exception) common to America and Europe are of the Atlantic realm. The exception is *Holmia rowei* of the Cordilleran region, but it will very likely be shown to belong to another genus related to *Holmia*.

The stem genus and the oldest of the family is *Nevadia*, giving rise in one line to *Callavia*, *Holmia*, *Wanneria*, and in the Middle Cambrian to *Paradoxides*. Another evolved into the remaining genera mentioned above, a branch that is not only the most specialized but also has the most characteristic genera of the family and of the Lower Cambrian. The evolution of this stock as worked out by Walcott demonstrates that the telson of

Olenellus is not homologous with the pygidium of most trilobites but that it is a specialized post-thoracic one at least 11 segments anterior to the pygidium in the most primitive genus of the family, namely *Nevadia*. In other words, when the specialized *Olenellus* is compared with the more primitive *Nevadia* it is seen that the former has not only lost its pygidium but at least 13 other post-thoracic segments, and that the telson of *Olenellus* is probably homologous with either one of the 15th to 17th post-cephalic segments of *Nevadia*, back of which in this genus there are still 11 other segments and the true pygidium. How these post-thoracic segments are lost and how the telson is developed out of a spine in the different genera is fully described and illustrated by the author. This unmistakable evolution probably also indicates that the telson of *Limulus* is not homologous with the pygidium of trilobites, but that it is as well a specialized thoracic segment, and one equivalent to a thoracic segment considerably in advance of the pygidium of its trilobite ancestors.

It is now also made more apparent that the head of the Mesonacidae is highly specialized in that the compound eyes have traveled from the ventral to the dorsal side in the earliest ontogenetic stages, for they have the relative position of maturity so early as in the paräprotopis stage. Further, the free cheeks are firmly united with the glabella, do not separate along the facial suture as in most trilobites, and in this again recall the similar condition in *Limulus*. Genera like *Olenellus* are, therefore, highly specialized trilobites and are decidedly removed from the primitive types of which *Atops* and *Conocoryphe* are examples.

For the first time the eye cavities in the Mesonacidae have been discovered and are here illustrated. They are very much like those in *Limulus*.

As is well known, the author is assembling Cambrian fossils from all parts of the world and in the work here reviewed we get a glimpse of the grandeur of the Smithsonian collections. When his studies are completed we will not only have a detailed knowledge of the oldest fossil faunas of the world but as well a firm base upon which to build our phylogenies of the trilobites, phyllo-pods and brachiopods. C. S.

4. *Die Bellerophonkalke von Oberkrain und ihre Brachiopodenfauna*; by F. KOSSMAT and C. DIENER, Jahrb. k. k. geolog. Reichs., 1910, pp. 277-310, pls. 14-15.—The Bellerophon limestone and dolomite of the eastern Alpine region are at the top of the Paleozoic section and in close connection with the Triassic. They are underlain by red and white sandstone and conglomerate that in turn rest upon the black slates of the Carboniferous. These littoral deposits evidently represent a new sea invasion and are correlated by Kossmat with the Grödener and Verrucano, the normal aspect of the southern Alpine Permian sandstone. Above the Bellerophon horizon there repose disconformably the sandy-micaceous Werfener beds of the Triassic characterized by *Pseudomonotis aurita*, *P. ovata* and *P. venetiana*.

This Permian limestone is often abundantly fossiliferous, but the diagenetic changes of these strata appear to have destroyed much of its life. On weathering the limestone is seen to be almost made up of *Diplopora* (calcareous algæ), what appear to be *Stenopora* (bryozoa), and foraminifera, but the *Fusulinidæ* are wholly absent. There are many other larger fossils, but these are rarely to be obtained in identifiable condition. Of these the most abundant species is *Productus* cf. *indicus*.

Diener identifies among others eight species of productoids, *Richthofenia* aff. *lawrenciana*, *Comelicania haueri* (the guide brachiopod of the Bellerophon limestone), *Hemiptychina* cf. *inflata*, and *Notothyris mediterranea*. The aspect of this fauna is, therefore, decidedly that of the *Productus* limestone of India and belongs in the Tethys faunal realm.

It is stated by Diener that the most abundant fossils are forms of *Productus* near *P. striatus*, *P. semireticulatus*, and *P. inflatus*, types that remind one very much more of the Pennsylvanian than the Permian. These are, however, the unprogressive forms and have not the stratigraphic value of the new brachiopod developments, such as *Richthofenia*, *Hemiptychina* and *Notothyris*. It is this contradictory associated evidence that has led Tschernyschew to regard the *Productus* limestone of India (which is of Permian age) as equivalent to the Upper Carboniferous of Russia, and which the reviewer opposed in this Journal for July and August, 1906.

Diener states definitely that the Bellerophon limestone and the *Productus* limestone are younger than the Upper Carboniferous. He adds: "The fauna of Schönbrunn and Schaschar (Upper Krain) teaches us that the anthracolitic brachiopods cannot be used [interprovincially] for detailed stratigraphic differentiation, even when the species are based upon trivial characteristics, although they may be so used in circumscribed areas as guide fossils in identical kinds of strata" (307). Further, that the Bellerophon limestone cannot be regarded as a transitional fauna to the Triassic. It is still rich in Paleozoic brachiopods, the corals and nautilioids are decidedly Paleozoic, while the few ammonites are of types occurring in the Permian and Lower Triassic of India. The bivalves are those of the Zechstein. The gastropods are somewhat more progressive in that the Triassic genera *Marmolatella*, *Platychilina*, *Hologyra*, and *Trachyspira* appear here for the first time, but in general the class is still Paleozoic. Therefore, the Bellerophon limestone is still Permian and has its clearest analogue in the *Productus* limestone of India.

Diener recommends that Waagen's term "Anthracolithic Epoch" be used for the combined Upper Carboniferous and Permian faunas because of the difficulties often locally encountered in separating these biota. Permo-Carbon cannot be so used as it is now applied to the Artinskian series. C. S.

5. *The Phylogeny of the Felidæ*; by WILLIAM D. MATTHEW. Bull. Amer. Mus. Nat. Hist., vol. xxviii, pp. 289-316 and 15

text-figures.—In this brief paper Dr. Matthew has added one more to his series of excellent and lucid phylogenies. He divides the Felidæ into two phyla, the earliest known examples of which are Oligocene, as no Eocene carnivora are known from which the Oligocene sabre-tooths can be derived.

The distinctions of the phyla are clearly indicated in limb, vertebrae, ribs, but especially in the skull and dentition, the phylum leading to the modern genus *Felis* having sub-equal canines above and below and powerful biting jaws by means of which the neck of the prey can be crunched. The other phylum culminates in the huge sabre-tooth *Smilodon*, with relatively feeble lower canines but with immense, curved, dagger-like upper teeth used for ripping open the neck of the huge contemporaneous pachyderms the vertebrae of which could not be crushed by the jaws.

The abundance of sabre-tooth types in early times is correlated with that of the pachyderms, including the elephants, rhinoceroses, etc., while with their replacement by a swifter, thin-skinned, ungulate fauna the sabre-tooths gave way to the better adapted felines. Dr. Matthew denies the contention that overspecialization of the canine due to "momentum of evolution" was the final cause of the extinction of this interesting race, though *Smilodon* has often been used as evidence of the truth of this somewhat doubtful factor of descent.

R. S. L.

6. *An Account of the Beaked Whales of the family Ziphiidæ in the collection of the United States National Museum, with remarks on some specimens in other American Museums*; by FREDERICK W. TRUE, Smithsonian Institution, U. S. National Museum Bulletin 73, pp. 1-89 and 42 plates.—The beaked whales which form the subject of this memoir are among the rarest of cetaceans with the exception of the bottle-nosed members of the genus *Hyperoodon*, the three genera *Mesoplodon*, *Ziphius* and *Berardius* being represented by about 100 known individuals more than half of which belong to the first-named genus. *Berardius*, the rarest, is known from about fourteen specimens altogether. Doctor True records but nineteen specimens of all the genera put together upon the east and west coasts of the United States. These specimens are represented by skeletons or skulls sometimes supplemented by photographs and casts and upon such material the main body of the work is based. On pages 76-77 is a list of the genera and species of existing ziphoid whales with their habitats. The illustrations are excellently reproduced half-tones, while the text gives a very clear and adequate knowledge of these strange cetaceans.

R. S. L.

7. *Report on the Resurvey of the Maryland-Pennsylvania Boundary part of the Mason and Dixon Line by the Mason and Dixon Line Resurvey Commission*, O. H. TITTMANN, WM. BULLOCK CLARK, ISAAC B. BROWN. Pp. 412, with 72 plates and 8 figures, 1908. Published by the Maryland Geological Survey as Vol. VII, WILLIAM BULLOCK CLARK, State Geologist, Baltimore, 1908 (Johns Hopkins Press).—This resurvey was carried

out by the United States Coast and Geodetic Survey at the request of the states of Maryland and Pennsylvania. The purpose was to accurately reestablish and mark the old line. The results show the high accuracy for the period of the work of the original survey from 1763 to 1768. A history by E. B. MATTHEWS of the various surveys of this line is also included. J. B.

8. *Maryland Geological Survey*, volume viii, 1908, WILLIAM BULLOCK CLARK, State Geologist. Pp. 486, with 26 plates and 27 figures. Baltimore, 1909 (The Johns Hopkins Press).—This volume contains an assemblage of papers. The first part deals with the highways, by WALTER WILSON CROSBY; the second part with the Maryland mineral industries, by WILLIAM BULLOCK CLARK and EDWARD B. MATTHEWS; the third part is on the limestones of Maryland with special reference to their use in the manufacture of lime and cement, by EDWARD B. MATTHEWS and JOHN S. GRASTY. The combination of scientific character and practical value which mark these papers indicates how valuable to a state a Geological Survey may be and still without duplicating the work of the national organization. J. B.

9. *Report of the Conservation Commission of Maryland for 1908-1909*, BERNARD N. BAKER, WM. BULLOCK CLARK, EDWARD HIRSCH, *Commission*. Pp. 204, with 13 plates and 13 figures. Baltimore, Dec. 31, 1909.—This report is the outcome on the part of Maryland of the Conference of Governors called by President Roosevelt at the White House on May 13-15, 1908. It contains chapters on mineral resources, agricultural soil resources, forest resources, reclamation of swamps, water resources, fisheries, oyster supply, game preservation, scenery, public health, good roads, recommendations. A perusal of these chapters calls attention especially to the present wasteful neglect of forests and public health. The value of the commission, if it succeeds in educating the public to the enactment and enforcement of needed state laws, will be almost incalculable. J. B.

10. *A Preliminary Report on the Geology of the Monarch Mining District, Chaffee County, Colorado*; by R. D. CRAWFORD. Pp. 78, with 11 plates and 3 figures. Bulletin I, Colorado State Geological Survey, Boulder, Col., 1910.—This report gives the geology of a region about five miles square situated on the east slope of the Sawatch Range. Ore was first discovered in 1878 and since that time the district has passed through various stages of prosperity, its fortunes at present being on the increase. The report is, therefore, of timely appearance. The district embraces an area of pre-Cambrian granite, partly enclosing an area of Paleozoic limestones underlaid by some quartzite. Across this older and deformed structure have broken massive intrusives of post-Devonian age. The mines are reported on in detail and the ores are classified under five types. J. B.

11. *Geology of the Grayback Mining District, Costilla County, Colorado*; by HORACE B. PATTON, CHARLES E. SMITH, G. MONTAGUE BUTLER, and ARTHUR J. HOSKIN. Pp. 111, with

11 plates, Bulletin II, Colorado State Geological Survey, Boulder, Col., 1910.—This bulletin is the result of six weeks' work in the field by students and teachers under the direction of the Department of Geology of the Colorado School of Mines during the summer of 1909. The tract surveyed embraces about thirty square miles lying due east of Blanca Peak, the highest peak of the Sangre de Cristo Range. Pre-Cambrian gneiss and mica schist on the west are flanked by Carboniferous sandstones and limestones. The latter are intruded by masses of diorite, monzonite porphyry, and felsite; certain large areas being so cut up by dikes that their separate mapping was impossible. An overprint pattern was, therefore, used to designate such areas. J. B.

12. *Erdbeben. Eine Einführung in die Erdbebenkunde*; von WILLIAM HERBERT HOBBS. Erweiterte Ausgabe in deutscher Übersetzung, von Professor Dr. JULIUS RUSKA. Pp. xxxii, 274, with 30 plates and 124 figures. Leipzig, 1910 (Quelle and Meyer).—It is pleasant to record that the work by Professor Hobbs on earthquakes has met with so favorable a reception that a German translation has been made. Studies of the most recent earthquakes, especially that of Messina, are included, and a chapter on the methods of building construction adapted to earthquake regions has been added. The volume considers the evolution of the science of seismology, the origin of earthquakes, the broad relations of earthquake regions on the earth, the detailed phenomena of earthquakes, local and distant effects, and methods of earthquake study, in the field and office. In the introduction Professor Hobbs calls attention to the rapid growth of the subject and its divergence into two distinct fields, that of the geophysicist, to be pursued by mathematical and physical methods, and that of the geologist, requiring field studies. J. B.

13. *Les Variations Périodiques des Glaciers* rédigé par Dr. ED. BRÜCKNER et E. MURET. Fourteenth report, 1908. Commission Internationale des Glaciers. Extrait des *Annales de Glaciologie*, iv., pp. 161-176, 1910. Berlin, 1910 (Frères Borntraeger).—As noted in the introductory paragraph, it is evident that during 1908 the retreat of glaciers was a general phenomenon. The marked growth of a group of Norway glaciers had diminished slightly in 1908. These and certain Swiss glaciers offer the only noteworthy exceptions in the table. The commission by this report continues to lay the basis for a future exact study of glacial variations and from them of climatic variations in various parts of the world. Such an accumulation of data for the use of the next and future generations is one of the most far-sighted movements of present science. J. B.

14. *Études Glaciologiques, Tirol Autrichien, Massif des Grandes Rousses*. Service d'études des Grandes Forces Hydrauliques (Région des Alpes) Ministère de l'Agriculture 1909. I.—*Forages Glaciaires à Grande Profondeur* par MM. FLUSIN et BERNARD. II.—*Études Glaciaires, Géographiques et Botaniques dans le Massif des Grandes Rousses* par MM. G. FLUSIN, C.

JACOB et J. OFFNER. Pp. vi, 112, plates iv+ix, maps iii.—In the preface attention is called to the great importance of complete investigation of the water resources of every region in order that the factors may be understood which control the run-off throughout the year. In the Alps not only do the lakes act as storage reservoirs but the glaciers also. The latter discharge their stores especially during the summer and also more abundantly during warm cycles of years, at the present time the glaciers being in general retreat. They thus act as storage reservoirs in ways different from lakes though equally important. Investigations upon glaciers have, however, been hindered by the lack of knowledge regarding their depth, the third dimension which is so readily ascertained for measuring the cross-section and run-off of rivers and lakes. The first part of the present work gives the details of the methods devised and successfully used for boring to the bottom of glaciers and thus determining their cross-section. The second part gives detailed studies and maps of the massif of the Grandes Rousses and its glaciers, the region where these methods were pursued. There is thus given here a very complete investigation of a group of glaciers considered as reservoirs of water stored in the solid form, a unique hydrologic investigation whose methods will doubtless be extended to other regions.

J. B.

15. *Beiträge zur Geologie der Samoainseln*; von I. FRIEDLÄNDER. Abh. k. Bayer. Akad. Wiss., II Kl., xxiv, Abt. III, pp. 509–541. Based on visits to all the main islands of the Samoa group, the writer gives a general sketch of their geological character and considerable detail regarding the most striking features of each. Since the islands are purely volcanic, it mostly concerns the arrangement and relative age of the new and old craters, lava masses and tuffs. The writer has visited also Hawaii and Fiji and, agreeing with Woolnough that the latter consists of volcanics piled on the remnants of a continental platform, he suggests that the volcanic masses forming the other two, if we consider them to rise wholly from the ocean floor, are of enormous dimensions, entirely beyond anything known on the land. In Hawaii, taking into account the small volcanic islands and coral reefs, the ridge stretches some 1500 miles with a maximum height of 30,000 feet. In Samoa the ridge is 300 miles long and 20,000 feet high. This suggests that these, like Fiji, are built on a submerged continental platform. Two maps and a number of excellent plates of photographs accompany the article.

L. V. P.

16. *Artificial Lava Flow and its Spherulitic Crystallization*.—Under this title in the August number of this Journal of the current year (p. 97), the writer described an accidental flow of glass, and the spherulites which formed in it. In the article it was stated that the conditions obtaining, and the relative positions of the specimens described, were unknown. Since then the writer has received a letter from Mr. R. L. Frink of Columbus, Ohio, a

technical engineer who has made a special study of the glass industry. Mr. Frink believes that it was an error to attribute the specimen figured in A of the plate to simple flowage. He sends a specimen which closely resembles it and says that these can be produced at will in the flattening ovens by laying sheets of glass one upon the other and submitting them to the action of heat for varying periods of time, and the longer the time the more opaque the mass will become. The latter statement refers to the greater number of minute spherulites. The specimen shows that the glass plates have been softened to a viscous condition, from the bent and wavy layers they present, and are completely welded. The plane of each two contiguous surfaces is marked by a white film composed of innumerable minute, white spherulites separated by clear green glass. In explanation of this it has been suggested to the writer that the film of air between the plates may have helped in the process. This seems quite possible, for as the glass softened, the gas may have rendered this layer less viscous, by entering into the molten solution, to the degree where crystallization could take place, while the intermediate layers were too viscous to permit of this. With respect to the specimen of Kane glass figured, it may be then, as Mr. Frink suggests, that it was not formed by actual flowage. A possible explanation for it may be that it represents successive droppings of portions of melted glass from the broken furnace upon one another, which flattened down, and along whose flattened surfaces the films of spherulites developed. It appears too thick and irregular to have been made purposely, as suggested by Mr. Frink.

In regard to the formation of spherulites in glass Mr. Frink says that he thinks that the difference in specific gravity between them and the glass is too slight to condition their arrangement, and that this is chiefly due to the viscosity, temperature, and flow of the glass. Sometimes they are at, or near, the surface; sometimes 12 or 18 inches below it there will be a stratum containing innumerable numbers of them. In general, the deeper ones are of larger dimensions. He regards them as being formed at the line of "mean flow," which may perhaps indicate one where the conditions are right for crystallization, being neither too hot on the one hand, nor too stiff and viscous on the other.

L. V. PIRSSON.

17. *Economic Geology*; by HEINRICH RIES. 3d edition. Pp. 589, 237 figs., 56 pls. New York (The Macmillan Company).—This work, originally published in 1905, has already gone through two editions and firmly established itself as a text-book of its subject. The book, in the present edition, has been revised and considerably amplified in scope and size. While its general arrangement remains the same, much more space has been devoted to the detailed description of the individual mineral districts. The number of the text illustrations has been increased nearly three times, while the number of the plates has been more than doubled.

W. E. F.

18. *The Ore Deposits of New Mexico*; by WALDEMAR LINDGREN, LOUIS C. GRATON and CHARLES H. GORDON. U. S. Geol. Sur., Professional Paper No. 68, 1910. Pp. 349, 33 figs., 22 pls.—The mining districts of New Mexico form a belt extending from the north central part of the state to the southwest corner. Silver or gold, or both, are present in nearly all of the districts and as a rule are accompanied by copper, lead and zinc. A great number of types of ore deposits are represented in New Mexico. Among them are copper and iron ores in sedimentary beds; fissure veins; mineralized shear zones; lenticular bodies; replacement deposits; contact metamorphic deposits; placers.

The pre-Cambrian schists contain disseminated ore in shear zones and veins of copper and zinc sulphides with some gold but little silver; the Paleozoic limestones carry irregular copper, lead and zinc deposits; the intrusive porphyries and granites contain fissure veins with gold and silver; finally, the rhyolite and andesite inclose fissure veins rich in gold and silver. The major part of the deposits occur in or near the many, usually small, areas of intrusive rocks—mostly monzonites—which extend across the state.

The study of the ore deposits of the state has resulted in the establishment of various periods for their formation with distinct characteristics for each period. Thus the pre-Cambrian deposits are mainly lenticular veins, shear zones and “fahlbands” in schists which carry chiefly gold and copper. In late Cretaceous or early Tertiary time widespread intrusion took place along what is now the mining belt. After these intrusions most of the metal deposits were formed; they consist of contact-metamorphic deposits, veins, shear zones and silver-lead replacements in limestone. In the latter part of the Tertiary period lava flows occurred in certain sections and at several places fissure systems in these rocks were filled with gold and silver ores. The age of the copper deposits in sandstone has not been fully established. Their formation probably commenced after the general uplift in the early Tertiary, when atmospheric waters began to penetrate the Red Beds, from which the deposits are believed to have concentrated their copper ores.

W. E. F.

19. *Meteor Crater in Northern Central Arizona*; by D. M. BARRINGER. Pp. 24, with 21 plates and maps (privately printed).—The Meteor Crater in Arizona, or Coon Butte as it was earlier called, is unquestionably one of the most remarkable spots on the earth and the problems that it presents have never been faced elsewhere. It has been described by numerous writers since attention was first called to it by A. E. Foote in 1891.* A very full and satisfactory account† of the locality and the associated meteoric material with a discussion of the origin of the crater was given by G. P. Merrill two years since in volume 1 of the Quarterly Issue of the Smithsonian Miscellaneous Contributions for January,

* See this Journal (3), xlii, 413, 1891.

† Ibid (4), xxv, 265, 1908.

1908 (pp. 461-498, plates lxi-lxxv). The present paper, the title of which is given above, was read by Mr. Barringer at the Princeton meeting of the National Academy of Sciences a year ago; it embraces the results of his own extensive explorations, and the conclusions drawn from them. The thoroughness with which the study of the locality has been carried on will be understood from the fact that no less than twenty-eight holes have been drilled in the central portion of the crater, some of them being carried to a depth of 1000 feet and more, below the level of the original plain.

The chief features of Meteor Crater, briefly characterized, are as follows: A crater-like depression a little more than three-quarters of a mile in diameter, with an average depth from the rim to the more or less level floor of about 570 feet. The walls, in part nearly perpendicular, are composed of limestone and underlying sandstone strata, which are tilted up and dip away from the center at varying angles. These strata, it is estimated, have been vertically lifted more than 100 feet from their original position, involving an uplift of perhaps some 20 to 30 million tons of rock. Further than this, many million tons of rock have been ejected from the crater. This includes great masses of solid limestone, from fifty to several hundred pounds in weight; the larger fragments lie near the crater's rim, the smaller ones extend to a distance of from one to one and one-half miles. The ejected rock material also includes the sandstone much of it in the form of "silica" or rock flour; this last makes up perhaps some 15 or 20 per cent of the entire material thrown out of the crater. Within the crater there are also enormous quantities of the sandstone which has been reduced to a fine pulverulent condition, while other portions are metamorphosed, a part showing a strongly marked slaty structure, and part, having undergone a kind of aqueo-igneous fusion, having a light, spongy consistency, with more or less opalescent quartz.

All of these phenomena, of the extent and magnitude of which it is difficult to form a conception, have been apparently accomplished without volcanic agency,* and are to be referred, as recent investigators agree, to the impact of an enormous meteoric mass of almost incredible size, such as we have no parallel for elsewhere on the earth. The writer concludes that "the crater was made, not by a single giant meteorite, but rather by a compact cluster or swarm of many thousand of shale ball meteorites and also possibly other iron meteorites traveling together as the head or part of the head of a small comet."

Many thousands of specimens of meteoric iron have been found in the neighborhood of the crater, up to over 1000 pounds in weight; some of the smaller ones have been found at a distance of

* Since the above statements were put into type, a paper on this locality by J. M. Davison has been published in *Science* (Nov. 18, p. 724). He returns to the idea of volcanic action, early suggested, and, speaking of the pulverulent sandstone, he remarks: "It rather suggests long-continued deposition of this powder, with occasional pieces of rock, by geyser action and a final explosion or series of explosions that closed the drama."

five and one-half miles from the crater. It was the discovery of these iron masses in 1891 that first attracted attention to this locality; they have been usually named from the neighboring Canyon Diablo. As is well known this meteoric iron has some important characters which need not be recalled here.

In addition to the iron, a unique feature of the locality are the "shale balls," of which great quantities have been discovered; the largest of these weighs something over forty pounds. These are generally rounded or globular disintegrating masses of meteoric iron and nickel oxide, many of them containing solid nickel-iron centers. They have more or less of a shaly structure. The iron of these balls contains chlorine in small amount, which is practically absent in the Canyon Diablo siderites and to this their disintegration is attributed. The shale balls, except when imbedded in the silica, oxidize to a hard compact iron shale, though often leaving an iron nucleus. The meteoric material exists not only on and near the surface but has also been brought up by the drills, often in the form of small specks of nickel-iron oxide, even from a depth of 680 feet below the floor of the crater, that is about 1200 feet below the original plain level.

It is, doubtless, disappointing that thus far the drills have failed to find the main mass of the projectile which did such a tremendous work; nor has it been located by experiments with the dipping needle. We must, however, accept the decision of the author, who says: "We are thus compelled to conclude that the mass which made the crater, and which, as has been suggested above, may have been the metallic head of a small comet, lies in the bottom of it somewhere; for if it was a compact cluster of iron meteorites which made the crater—there is certainly a great deal of evidence in favor of this theory and none against it—it would seem from the evidence most unlikely that any considerable portion was expelled after the cluster had penetrated some 1100 to 1200 feet of limestone and sandstone strata. When the metallic mass is found, it would seem probable that it will be found to have partially oxidized, much after the manner of the buried shale balls, in which event it would still possess great commercial value. As yet we do not know where it is in the large area covered by the crater, but I personally think it probable that, in the form of a vast number of shale balls and perhaps Canyon Diablo siderites lying more or less closely together, most of it will be found far over in the southern or southeastern portion of the crater, where no prospecting by the drill has been done, and that some of it, if not the larger part of it, will be found underneath the perpendicular cliffs which form the southern wall."

Mr. Barringer's memoir, of which only a brief account has been given, closes with a bibliography of the subject, and is accompanied by a large number of fine plates, giving views of the crater from different points, the masses of limestone rock thrown out from it, and also many illustrations of the altered sandstone, the shale balls and iron in their various forms.

III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *The National Academy of Sciences*.—The autumn meeting of the National Academy was held at St. Louis on Nov. 8 to 10. The following is a list of papers read :

GEORGE C. COMSTOCK : Some problems of stellar motion.

EDWIN B. FROST : Preliminary note on the Sun's velocity with respect to stars of spectral type A.

FOREST R. MOULTON : On the origin of binary stars.

JOHN M. COULTER : The Cycadophytes.

WILLIAM TRELEASE : A monograph of *Agave* in the West Indies.

REGINALD R. GATES : The mode of chromosome reduction.

WILLIAM M. DAVIS : The Front Range of the Rocky Mountains in Colorado.

GEORGE T. MOORE : Mutualism, parasitism and symbiosis.

JOHN U. NEF : Sugar chemistry from the new chemico-physical standpoint,—or the behavior of the sugars toward enzymes, alkalies and oxydizing agents.

WILLIAM A. NOYES and LUTHER KNIGHT : Molecular rearrangements in the camphor series : isocamphoric acid.

IRA REMSEN : A molecular rearrangement leading to the formation of anidines.

On Tuesday evening a lecture was delivered by Prof. T. C. Chamberlin on China.

2. *Maryland Weather Service*, WM. BULLOCK CLARK, Director, Vol. III; *The Plant Life of Maryland*; by FORREST SHREVE, M. A. CHRYSLER, FREDERICK H. BLODGETT and F. W. BESLEY. Pp. 533, with 39 plates and 15 figures. Baltimore, 1910 (Johns Hopkins Press).—Of the two volumes previously issued in the Maryland Weather Series, the first discussed the physiography and the meteorology of the State, and the second contained a study of the climate and weather of Baltimore and its vicinity. The present volume has a somewhat wider range, dealing with the plant life of the State, particularly as regards its distribution, not only as affected by climate and the physiography of the three prominent zones, but also determined by the nature of the soil. In 1904 a botanical survey of the State was undertaken by Dr. Forrest Shreve, and the important results of the work done by him and his associates are now presented to the public. The close association of the Geological Survey with the Weather Service, both being under the directorship of Professor Clark, has been a fortunate arrangement for the state, both as regards economy of management and the thorough coöperation of the investigations.

3. *International Institute of Vulcanology at Naples*.—At the recent Geological Congress held in Stockholm, a proposal was made by Dr. IMMANUEL FRIEDLÄNDER for the establishment of an International Institute of Vulcanology at Naples. This plan was accepted by the Congress and a circular has recently been issued giving details and calling for contributions to this important cause. The Institute, when established and fully equipped,

will, for the first time, provide for continuous and systematic observations of all volcanic phenomena, both physical and chemical. How important results may be looked for from this enterprise may be fairly estimated from the value of what has already been done by the small and meagerly supported observatory on Vesuvius. It is proposed to raise before January, 1912, a building fund of 1,500,000 lire, while promises of annual contributions aggregating 50,000 lire are also needed. Dr. Friedländer leads the list of contributions with the sum of 100,000 l. for the fund and 10,000 l. as an annual contribution for ten years; it is to be hoped that his appeal may have generous support. His address is Villa Hertha, Vomero, Naples.

4. *Studies in Spiritism*; by AMY E. TANNER. With an introduction by G. STANLEY HALL. Pp. xxxix, 408. New York, 1910 (D. Appleton & Co.).—This is a thoroughly sane and fair-minded presentation of a subject in which great interest is felt, and about which there is a wide divergence of opinion. The statements of the author and her observations based upon repeated sittings with Mrs. Piper will appeal all the more strongly, at least to those who tend to be sceptical in regard to matters connected with telepathy and spiritism, in that she entered upon her work not "with any spirit of antagonism, but rather in a spirit of doubt that inclined towards belief." The conclusion to which her investigations have led her are expressed as follows: "I was inclined to think that I should finish the work a believer at least in telepathy. So far is this from being the case that the more I have read and seen of such experiences, the more amazing has it come to seem that two theories like telepathy and spirit communication, which are unsupported by any valid evidence, should have obtained credence to-day; and the more incomprehensible has it come to be that men should be willing to stake their professional reputations upon the inaccuracies and rubbish that pass for 'scientific' facts in these matters . . ." The volume was undertaken at the suggestion of Dr. G. Stanley Hall and has been prepared under his supervision; the introduction is from his hand.

Psychism; by Mr. HUME. Pp. 157. London and Felling-on-Tyne (The Walter Scott Publishing Co.).

OBITUARY.

WILLIAM HENRY BREWER, Professor emeritus of Agriculture in the Sheffield Scientific School of Yale University, died at New Haven on November 2 at the age of eighty-two years. A notice will be given in a later number.

DAVID P. PENHALLOW, Professor of Botany in McGill University, Montreal, died on October 26 at the age of fifty-six years.

Dr. OTTO LUEDECKE, Professor of Mineralogy at the University of Halle, died in October at the age of sixty-six years.

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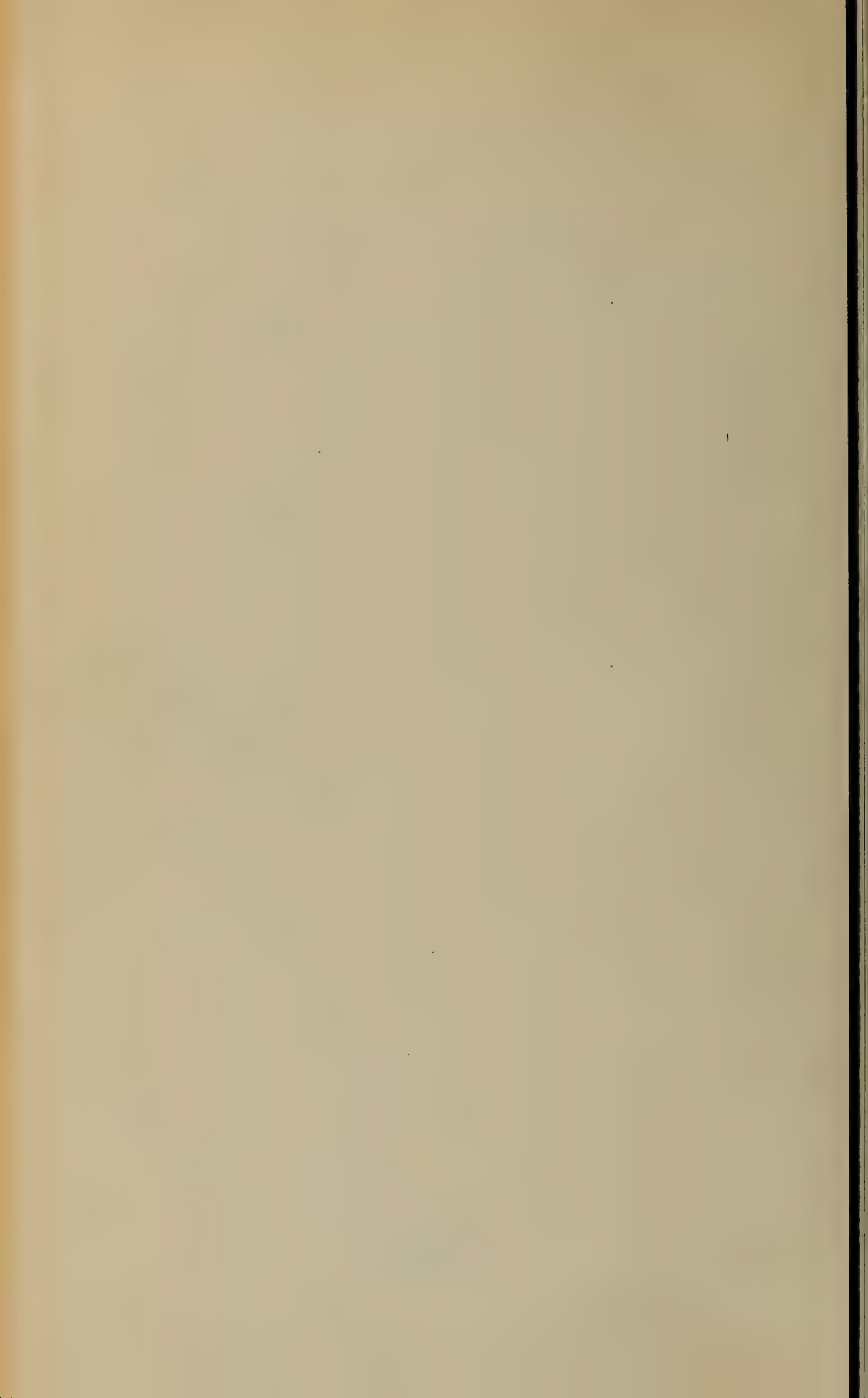
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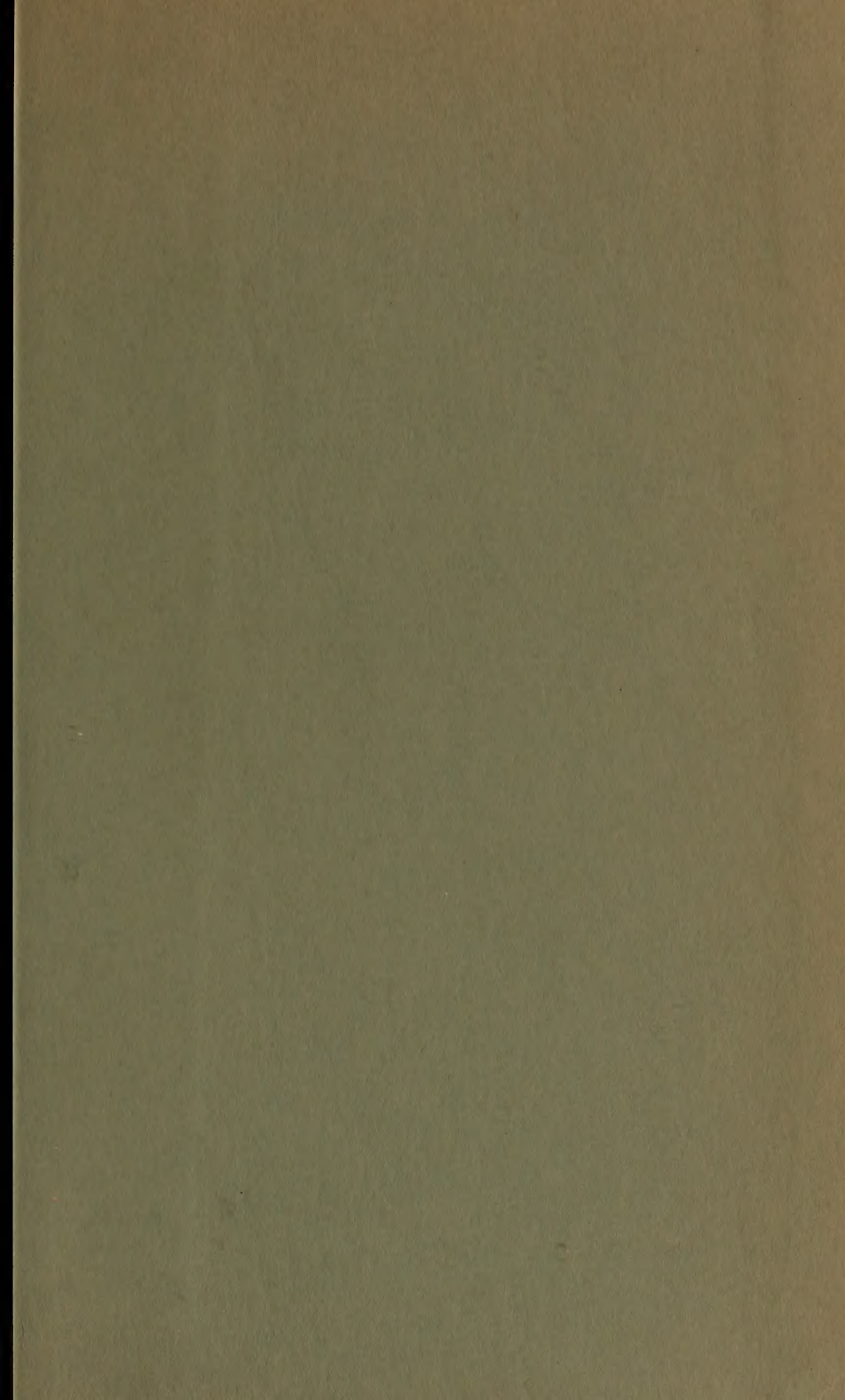
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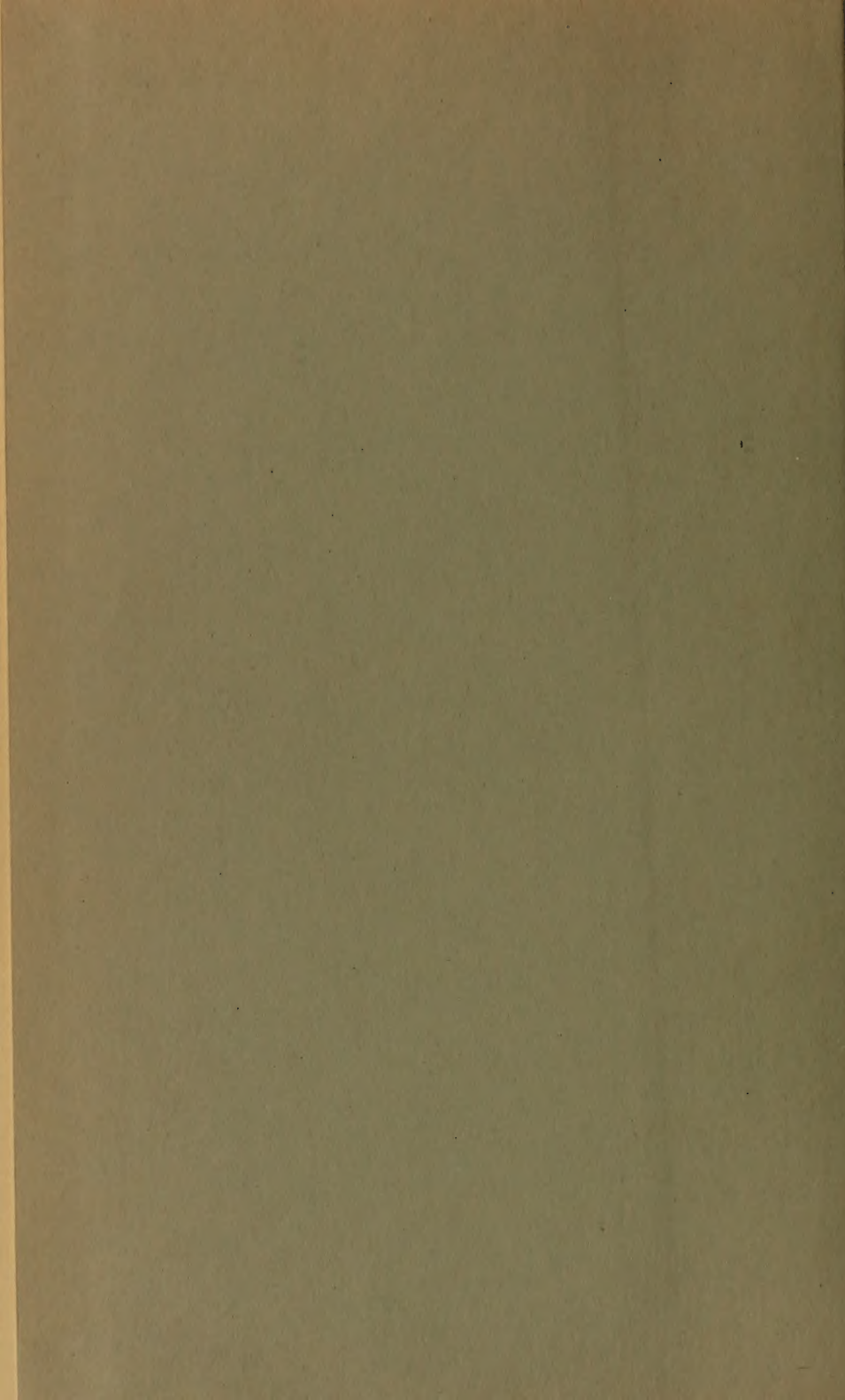
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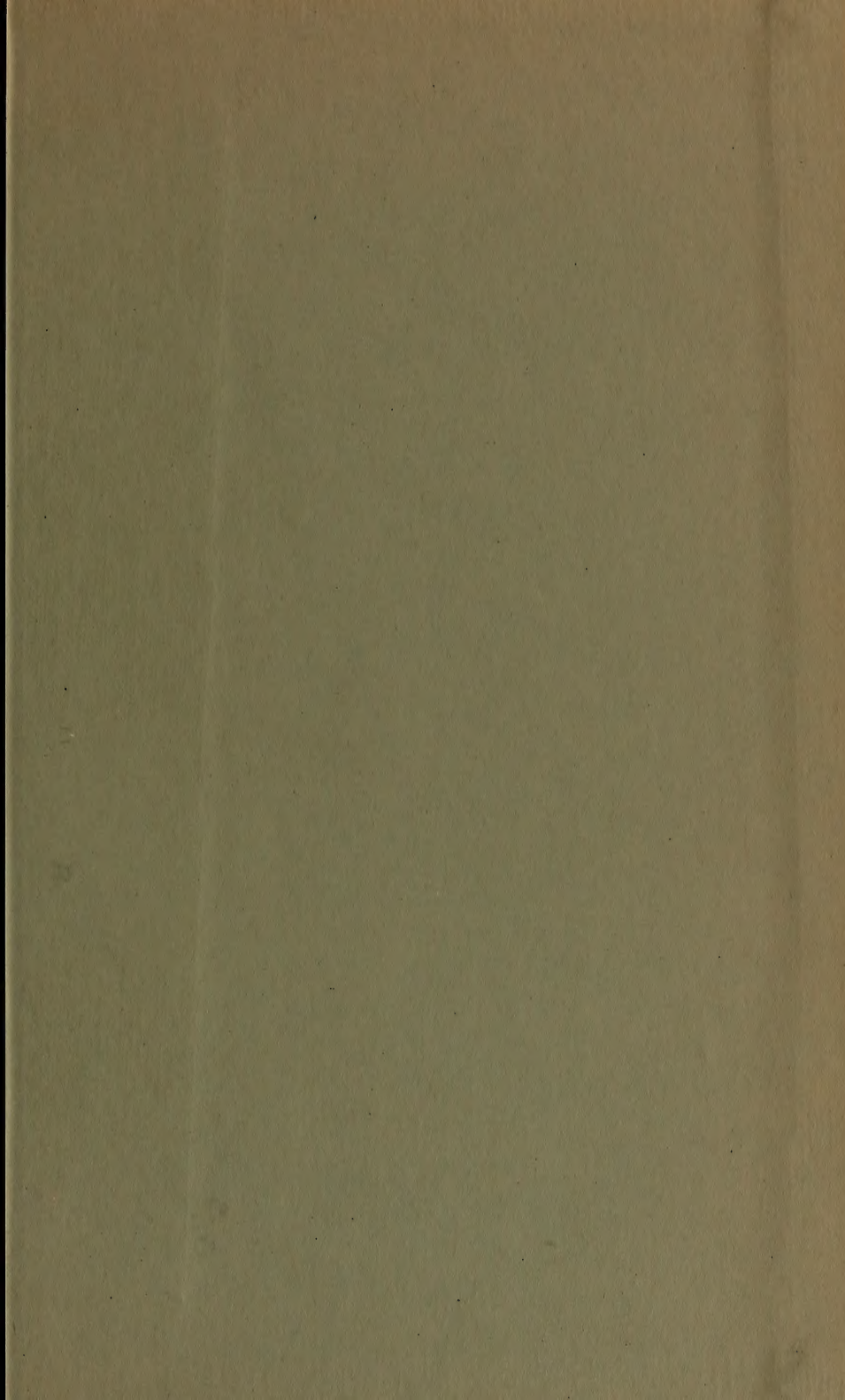
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